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THE UNIVERSITY OF ALBERTA

ECONOMIC APPROACHES TO ENVIRONMENTAL MANAGEMENT OF THE ALBERTA TAR SANDS

by

DAVID HENRY McGECHIE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ECONOMIC APPROACHES TO ENVIRONMENTAL MANAGEMENT OF THE ALBERTA TAR SANDS submitted by DAVID HENRY McGECHIE in partial fulfilment of the requirements for the degree of Master of Arts.

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ABSTRACT

Development of the Alberta tar sands is an enormous and extremely complex undertaking. As development proceeds, the quality of the natural environment will come under increasing pressures and, to some extent, this quality will be forfeited. The Alberta Conservation and Utilization Committee, in their "Fort McMurray Athabasca Tar Sands Development Strategy", claimed that the "basic impact" on the environment would amount to

> . . . partial to total denudation of the surface vegetation, partially disrupted to totally obliterated surface hydrology, extensive changes to the groundwater regime caused by increasing injections and recharge capability modified by a vastly increased permeability rate of the bituminous depleted sands, altered topographical land-forms caused by the deposition of spent tailings or the subsidence of depleted sands, massive withdraws of surface water from streams and rivers causing physical changes to their stream flow characteristics, heated effluent waters resulting in chemical and biological changes to the receiving waters and atmospheric changes such as ice fog during the winter, atmospheric gaseous emissions containing sulphur dioxide and other compounds, all of which will have disruptive effects on the remaining flora and fauna because of the massive ecological changes.

One of the key problems before decision makers, therefore, is to control and regulate the extent and nature of these potential environmental effects. The deci-

sion makers, however, must have a framework or set of guidelines upon which to base their policies if they are to approach the desired end of maximum net social benefits. The aim of the present study is to aid in building such a framework or set of guidelines. To begin with, the theoretical nature of the environmental problems--that of external effects--is discussed. Given the theoretical basis of the problem, models of reclamation and residuals management are presented. Common to both sets of models is the view that a regional approach, as opposed to a lease by lease approach, is necessary if we are to realize the desired goal of maximum net social benefits. The actual construction and implementation of these models will present formidable problems to the decision makers, and problems that are not likely to be overcome in the near future. In the interim, until the models are operationalized, policies must be devised that will insure that any "immoderate" damages attributable to imprudent development are avoided. The present study attempts to develop the conceptual basis for such policies.

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CHAPTER I

INTRODUCTION

This study examines economic approaches to environmental management of the Alberta tar sands. The actual rate and scale of tar sands development is largely uncertain, but whether there is only one plant in the area or twenty, the environment will be affected. One of the problems before policy makers, therefore, is to control and regulate the potential environmental impacts of development. The concepts and models in the present study offer a possible set of guidelines to aid in these decision making processes.

Policy Background and Resource Potential

In October of 1962, after the approval of the Great Canadian Oil Sands (GCOS) application, the Social Credit government of Alberta issued a policy statement with respect to tar sands development.[1] As owner of the resource in question, the government felt that it had the responsibility to regulate the timing and the extent of tar sands production, not only in line with the interests

of the public, but also in the interests of the conventional oil industry of Alberta. In fact, production from the tar sands would be allowed to reach only those markets not then serviced by the conventional industry, or thought to be so serviced in the foreseeable future. Hence, tar sands production was to supplement, not displace, conventional oil.

In February of 1968, the Social Credit government found it necessary to reconsider its tar sands policy in light of developments in the United States.[2] What markets were to be considered "beyond reach" of the conventional industry needed clarification. The "beyond reach" markets were to include those markets not then being serviced, nor expected to be serviced in the foreseeable future, by the conventional industry because of price or quality specification. Moreover, where it could be demonstrated that a tar sands applicant's marketing proposal would encourage growth in the total crude oil market beyond that which would otherwise occur, then the government was prepared to authorize further tar sands production. The tar sands production, however, was to account for no more than fifty per cent of this "new" market if said market was "within reach" of the conventional industry.[3] The emphasis was still on supplementing, not displacing, the conventional industry.

> Accordingly, the total volume of conventional oil sands production . . . that will be permitted to enter new markets within reach of the conventional industry will be restric-

> ted to 150,000 barrels per day. Unless some wholly unforeseen set of circumstances should develop this limit will remain in effect for five years. During this period the limit will be reviewed and, if conditions warrant, it may be increased for a succeeding period.[4]

In September of 1973, G. W. Govier, chairman of the Alberta Energy Resources Conservation Board (ERCB), stated that the proven remaining recoverable reserves of conventional oil in Alberta had declined since 1968.[5] To stem the decline, Govier called for increased oil sands production.

The Alberta oil sands are situated in four primary deposits (Athabasca, Cold Lake, Peace River and Wabasca) with a combined area in excess of twelve million acres. (See Table I-1 for summary.) With the extractive technology still in its infancy, only those sands amenable to strip-mining (i.e. containing 5 or more weight per cent crude bitumen, under 150 feet or less of overburden, and with an overburden to pay ratio of less than one) are classed as "proven recoverable" by the ERCB.[6] With these criteria and assuming a 90 per cent mining recovery rate, the ERCB estimates the total recoverable reserves of crude bitumen at 38 billion barrels, all of which is located in the Athabasca deposits. Given the GCOS experience, and the Syncrude estimates, the ERCB assumes a 70 volume per cent separation and conversion of recoverable crude bitumen to synthetic crude--hence, the estimate of 26.6 billion barrels of synthetic crude oil for the tar sands reserves.

TABLE I-1

PROVED RESERVES OF CRUDE BITUMEN AND SYNTHETIC CRUDE OIL IN ALBERTA
DECEMBER 31, 1972

DEPOSIT	OVERBURDEN DEPTH INTERVAL (FEET)	AREAL EXTENT (M ACRES)	AVERAGE PAY THICKNESS (FEET)	AVERAGE CRUDE BITUMEN SATURATION (FRACTION BY WEIGHT)	INITIAL CRUDE BITUMEN IN PLACE (MMSTB)	INITIAL RECOVERABLE CRUDE BITUMEN (MMSTB)	INITIAL RECOVERABLE SYNTHETIC CRUDE OIL (MMSTB)
Athabasca	0-50	80	104	0.098	12,400	10,300	7,200
	50-100	210	103	0.100	32,700	18,900	13,200
	100-150	200	94	0.102	28,900	8,800	6,200
	150-250	270	112	0.102	46,500		
	250-500	590	104	0.096	88,900		
	500-1000	2,100	67	0.098	209,500		
	1000-2000	2,300	59	0.100	207,000		
Cold Lake A	1000-2000	1,800	53	0.080	117,900		
Cold Lake B	1000-2000	650	40	0.081	32,700		
Cold Lake C	1000-2000	710	16	0.076	13,500		
Peace River	1000-2000	360	38	0.074	15,900		
	2000-2500	820	37	0.074	34,500		
Wabasca A	250-500	91	25	0.100	3,500		
	500-1000	619	32	0.084	26,000		
	1000-2000	54	11	0.101	900		
Wabasca B	1000-2500	1,000	26	0.059	23,400		
Totals		12,013			895,100	38,000	26,600

Source: ERCB

> The presently proved reserves of synthetic crude oil are some 4 times that of conventional crude oil, 17 times that of the combined natural gas liquids, 3 times that of natural gas, 4/5 that of coal and thermally equivalent to 1800 years' generation of Alberta's proved hydro electric capacity. Comparing ultimate reserves, we see the synthetic crude oil reserves are 16 times that of conventional crude oil, 85 times that of the total natural gas liquids, 2½ times that of coal and thermally equivalent to 6800 years' generation of Alberta's ultimate hydro electric capacity.[7]

While one must concede that the tar sands have a tremendous potential in the overall world energy situation, one must keep in mind that the realization of this potential could prove costly, especially from Alberta's standpoint. As yet, only one commercial plant is on stream, one is under construction, and several sit on the drawing boards;[8] but already much concern has been expressed as to the impact of multi-plant operations on the quality of the environment.

Nature and Scope

As development of the tar sands proceeds, it is expected that the quality of the environment will come under increasing pressures, and that there will be a growing divergence between private and social costs. In the words of one author,

> . . . the entire hydrosphere, biosphere and lithosphere (and to some degree even the atmosphere) . . . will be obliterated or very substantially altered.[9]

In general, there has been a tendency within the economic literature to consider externalities as rather exceptional phenomena which can be dealt with adequately through some ad hoc arrangement. This view ignores the fact that technological externalities are an inevitable, if not inherent, part of the production activities of a dynamic economy. In order that we may construct the necessary models to deal with these problems within the present context of tar sands development, a thorough understanding of the theoretical basis of the concept of externality is desirable. A brief survey and discussion of the relevant externality literature, therefore, becomes the first objective of this study, and is presented in Chapter II.

Given the theoretical basis of the externality problem, the second objective of this study is to develop, albeit nonquantitatively, models of reclamation and residuals management. Common to both sets of models is the view that a regional approach, as opposed to a lease by lease approach, is necessary if we are to realize the desired goal of maximum net social benefits.

The reclamation models presented here are of two types. The first type attempts to demonstrate the optimum degree of reclamation given some level of strip-mining activity, i.e. so many acres "disturbed". Alternatively, we can assume that the level of activity is a variable in the analysis. This approach would afford

greater flexibility to the policy makers in their attempts to maximize net social benefits with respect to tar sands development. Both types of reclamation models are developed in Chapter III.

Reclamation considerations are but one of the environmental problem areas. Development of the tar sands, with its consequent residuals generation, will undoubtedly put a strain on all of the environmental media. The traditional approach to residuals management problems has been to consider the different forms that the residuals might take, or the different media to which they may be discharged, as separate problems. Many of the residuals, however, can be readily transformed from one form into another, or discharged into another receiving medium. For example, some authorities believe that Syncrude could reduce its estimated sulphur dioxide emissions from 287 long tons per stream day (LT/ST) to 40 LT/SD through the application of the best practicable technology.[10] The installation of this technology may very well reduce the environmental problems stemming from sulphur dioxide emissions, but what still remains to be considered is the fate of the 247 LT/SD of sulphur dioxide that has been removed from the smoke stacks. Clearly, the pollution abatement equipment has not placed these residuals into some void. In essence, the gaseous residuals problem has simply been transformed into a solid or liquid residuals problem. The form of the residual has been altered, but the substance

remains. Thus, while the traditional approach to residuals management may be more tractable, it may lead to serious oversimplifications. A more comprehensive approach, as suggested by the regional residuals management model of Chapter IV, may prove desirable for such as the tar sands.

The construction and implementation of the reclamation and residuals management models present formidable problems, and problems that are not likely to be overcome in the near future. Development of the tar sands, and the subsequent environmental ramifications, however, will continue. In the interim, until the models are operationalized, steps must be taken to ensure that any "immoderate" damages attributable to hasty development are avoided. The third objective of this study, therefore, is to develop a conceptual approach to the decision making process that will ensure that the "safe minimum standards" associated with the various development parameters are not encroached upon. This objective is developed in Chapter V.

Footnotes

[1]Reprinted in Walwyn, Stodgill and Co., "A Look at World Energy: The Athabasca Tar Sands" (June 1973), pp. 39-45.

[2]It was becoming more and more apparent that the U.S. was heading toward greater deficiencies of supply, and there was the possibility that oil-from-shale and oil-from-coal might be promoted to fill the gap. Therefore, increased tar sands production might capture some of this market and retain its edge over alternative U.S. sources.

[3]The government defined a "new" market as one that was not then being served; one that was over and above the normal growth in existing markets; or one that represented a net increase in total market.

[4]Walwyn, Stodgill and Co., "World Energy", p. 44.

[5]G. W. Govier, "Alberta's Oil Sands in the Energy Supply Picture", talk to the 1973 C.S.P.G. Symposium (Calgary, 7 September 1973).

[6]To exploit the deeper deposits, some method of *in situ* bitumen extraction will have to be employed. These methods will separate the bitumen from the sand in place beneath the ground. While many such methods are being tested within the tar sands area, none have as yet proven economically feasible. With their development, and subsequent application, a new set of environmental problems will evolve. The present study deals primarily with those environmental problems associated with strip-mining operations.

[7]Govier, "Energy Supply Picture", p. 18.

[8]GCOS is the only operator presently on stream; Syncrude is in the construction phase; and Shell, Petrofina, and Home-Alminex have approval from the ERCB but not from the Cabinet.

[9]Wade Rowland, *Fuelling Canada's Future* (Toronto: Macmillan, 1974), p. 80.

[10]Regional DOE Syncrude Task Force, "Environment Canada Comments Relating to Documents Comprising the Syncrude Environmental Impact Assessment", (19 August 1974), pp. 3-4.

CHAPTER II

ON THE CONCEPT OF EXTERNALITY

Various authors have voiced their dismay that such a key concept as externality--which is ". . . central to the neo-classical critique of market organization" and ". . . dominates theoretical welfare economics and, in one sense, the theory of economic policy generally"[1]--has lacked operational and usable definitions.

> If the cutting edge of this powerful analytic tool is to be restored, some attempt must be made to chip away much of the accumulating accretions of meaning that have attached themselves to this term over time.[2]

The purpose of this chapter, therefore, is twofold. First, the meaning of the term, and its significance with respect to the allocation of society's resources and the distribution of income, will be dealt with briefly. Secondly, the broad range of policy alternatives that exist to deal with external effects will be discussed.

Defining Externalities

For an externality to exist, some authors insist

that two requirements must be met.

> Condition 1. An externality is present whenever some individual's (say A's) utility or production relationships include real (that is, nonmonetary) variables, whose values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare.[3]

In mathematical terms, an externality is present when:

$$U^A = U^A(X_1, X_2, \ldots, X_m, Y_1)$$

i.e. individual A's utility depends upon those consumption activities ($X_1, X_2, \ldots, X_m$) which are under his exclusive control, as well as upon the consumption or production activity Y_1, which is under someone else's (B's) control. The individual will attempt to maximize his utility in the "ordinary" way, subject to the externally determined values for Y_1 (i.e. if the value of Y_1 should change, individual A will modify the values for the X's accordingly).[4]

> Condition 2. The decision maker, whose activity affects others' utility levels or enters their production functions, does not receive (pay) in compensation for this activity an amount equal in value to the resulting (marginal) benefits or costs to others.[5]

Some authors, most notably Buchanan and Stubblebine, contend that interdependence per se (condition 1) implies externality. In their view, if the externality is priced, then it may cease to be "relevant" but the externality itself remains, at least to some degree.[6]

Another controversial point in the literature centers around the importance of pecuniary externalities.[7] With this type of externality, changes in the level of demand (i.e. changes in the prices of some inputs or outputs) affects the financial circumstances of a third party. In effect, pecuniary effects are reflected in changing prices and profits, not in altered technological possibilities. Seen in this light, pecuniary externalities are but transfers from one sector of the economy to another, via changes in relative prices, and present no problem for a market economy. Hence, Mishan concludes that the term is "superfluous and possibly confusing".[8]

The Reciprocal Nature of the Problem

A classic example of an externality is that of smoke from a factory which has detrimental effects on the local laundry. The traditional approach to remedy this divergence between private and social costs is quite straightforward. Since the factory emitted the smoke, it, or its owner, is deemed liable and as such must make amends with those adversely affected. By forcing the firm to internalize all of its costs, the externality would cease to exist, or become irrelevant. Things, however, ". . . have not seemed nearly so simple since R. H. Coase presented his analysis of social cost."[9]

Coase argued that the traditional approach tended to obscure the nature of the "choice" that has to be made.

> The question is commonly thought of as one in which A inflicts harm on B and what has to be decided is: how should we restrain A? But this is wrong. We are dealing with a problem of a reciprocal nature. To avoid the harm to B would inflict harm on A. The real question that has to be decided is: should A be allowed to harm B or should B be allowed to harm A? The problem is to avoid the more serious harm.[10]

Furthermore, once the parties involved realize their interdependence, and given that they are profit or utility maximizers, each will be motivated to partake in voluntary and mutually satisfactory arrangements that will lead society as a whole to a more optimal allocation of resources without the need for governmental intervention. For example, assume the factory is not held responsible for any damages associated with its emissions. In this case, if the damage to the laundry is greater than the benefit that the factory derives from its operations, then there exists some range of mutual gain (i.e. the factory could be bribed to reduce its emissions). Had the liability rule been reversed, the factory may find it profitable to bribe (compensate) the laundry for permission to increase its emissions.

Turvey takes the analysis a step further.[11] How much the laundry suffers will depend not only upon the scale of the factory's activity but also upon the precise nature of this activity and upon the laundry's reaction to it. The laundry's loss would be a function of the quantity of smoke emitted, the height of the factory's chimney, and the costs to the laundry of installing air-conditioning,

indoor clothes-dryers and/or any other methods that could reduce the effects of the smoke.

> Thus to ascertain the optimum resource allocation will frequently require an investigation of the nature and cost, both of alternative activities open to A [the factory] and of the devices by which B [the laundry] can reduce the impact of each activity. The optimum involves that kind and scale of A's activity and that adjustment to it by B which maximizes the algebraic sum of A's gain and B's loss as against the situation where A pursues no diseconomy-creating activity.[12]

A much more controversial aspect of the Coase analysis centers around the theorem on allocative neutrality--the Coase Theorem. This is the subject of the next section.

On the Questionable Theorem of Allocative Neutrality

The Coase Theorem has led to much "intellectual unease" with respect to its supposed "neutrality" and its apparent "amoralization" of externality policy.[13] Briefly stated,

> . . . under idealized conditions when transactions costs are absent and where income-effect feedbacks are not relevant, the allocational results of voluntarily negotiated agreements will be invariant over differing assignments of property rights among the parties to the interaction.[14]

Returning to the earlier example, under these "idealized" conditions, the laundry could bribe the factory to reduce its smoke emissions. This bribe represents an opportunity cost to the factory and, therefore,

is an incentive for it to reduce its emissions. If on the other hand, the factory is deemed to be liable for all damage, the factory owner will be forced to pay an explicit cost if he continues with the emissions or if he installs pollution abatement equipment. No matter who holds the property rights, transactions will continue until the sum of the laundry's damage costs and the factory's control costs are minimized. Hence, the allocation of resources is not affected by the assignment of property rights--but this assignment does affect the distribution of gains and losses between those concerned.

> Surely decent people could see a moral problem in poor citizens bribing an affluent producer of effluents, or accepting pollution in defenseless silence, while Coasians looked on benignly.[15]

Moreover, the probable fulfillment of the necessary assumptions is most unlikely. Several authors have criticized the theorem at length, focusing primarily on the income transfer effects and the transactions costs. Samuels, for example, claims that the theorem is

> . . . a very limited partial-equilibrium proposition which concentrates upon certain variables to the exclusion of others which dominate the actual operation of those included, thereby giving effect to certain variables even while seemingly abstracting from them. Thus when all the important variables are considered, the thrust of the theorem is shown to be not only incomplete, imprecise and ambiguous, but also reversed.[16]

Randall[17] and Dolbear[18] contend that a change in legal responsibility is one such neglected variable. In the consumption case, a change in the liability rule would

change the budget constraints of the concerned parties, and there may be an income effect. Randall extends the analysis to the producers' case where capital is scarce. Here the change in the liability rule affects the capital constraints of the producers.

Due and Friedlaender provide some useful insight into these areas.[19] They point out that there are two relevant magnitudes to take into account when considering policy changes that affect persons' welfare. The first, "compensating variation", is a measure of the maximum sum one would be willing to pay to ensure that some beneficial change happens. The second is referred to as the "equivalent variation", and measures the minimum sum one would require as compensation to accept a detrimental change. With the aid of a few examples, the authors demonstrate that these sums are by no means equal. In particular,

> . . . the maximum sum a person would be willing to pay to experience a beneficial change is less than the minimum sum a person would require to undergo a detrimental change. When the welfare changes are substantial, the maximum sum a person will pay for a beneficial change must be limited by his available resources, while the minimum sum he would require as compensation for a detrimental change has no such constraint.[20]

Samuels reinforces these ideas contending that the Coase theorem, and Pareto-optimality for that matter, neglects the "driving force" of wealth and income distribution in economic activity, not to mention the "power

plays" over such distributions.[21] Included in the "struggle" is the manipulation of property and liability rules for distributional effects with the manipulative potential being a "partial function of the status quo power structure."[22] It would seem, therefore, that

> . . . the allocation of resources contemplated by the theorem is not a unique allocation, whether deemed Pareto optimal or not. The allocation of resources is a function of and is specific to the power structure that gives rise to it . . . . Property rights constrain the field of feasible outcomes, define the Pareto-domain, and govern the allocative outcomes' substantive composition.[23]

> . . . It is on the basis of rights that economic actors are able to influence the allocation of resources, i.e., rights govern the identity and positions of participants with respect to the utilization of scarce resources. Where a person has a right which others must respect, the others are perforce less well situated, and the right holder more well situated, with regard to influencing allocation.[24]

One of the crucial assumptions underlying the Coase theorem is that transactions costs are absent. This would hardly seem to be the case in the real world. Mishan claims that "any movement by any method toward such improvements [reduction of Pareto relevant externalities] involves a variety of costs."[25] In the case of voluntary agreement between two parties, Mishan divides the transactions costs into three categories. The first category pertains to the initial costs leading up to negotiations between the concerned parties;[26] the second, to the capital expenditure required to implement the agreement; and the

third, to the costs of maintaining the agreement.

Another observation made by Mishan, which is vaguely alluded to above, is that it cannot be assumed that transactions costs will be the same no matter who is deemed liable. This "inequality" of transactions costs has serious implications in cases of environmental concerns. Here, one would expect transactions costs to be much larger where the initiative must come from a large and diffuse group of individuals as opposed to the case where the initiative is in the hands of a smaller group of entrepreneurs. Under the former case, there is a certain loss of time and effort plus the risk of substantial and irrecoverable expenses in attempting to unite the group. In the case of industry liability, no personal risk is involved and the time and effort component is much more of a routine activity than under the previous case. Furthermore, given that industry is deemed liable, one might expect that firms will, to some extent, avoid investment in pollution-prone products. On the other hand, with pollution damage costs entering into their cost structure, the firms will have an incentive to engage in pollution-reducing technological research and development, or perhaps to move to more remote areas where pollution control costs will not be as great.[27] However, if the industry is not deemed liable, there would be little incentive for the firms to conduct such research or to relocate, with a consequent misallocation of resources as they ignore the pos-

sibilities of potentially greater social gains. It becomes quite apparent, as Randall concludes, that in cases of industrial pollution, it is much more likely that transactions costs will be too high to achieve a solution other than the status quo where the initiative falls not on the polluting industry, but on those adversely affected.[28]

An interesting variation, but a similar conclusion, is brought out by D'Arge.[29] He maintains that if we take the Coase assumption of "universality" of markets with zero transactions costs to the limit, then one must consider that a market for liability or legal rules could emerge. Obviously those that have the most resources at their disposal (industry) are in the more favorable position to influence which liability rule would be "bought". And as Samuels might add,

> The liability rule has allocative consequences in part because the rule governs the status quo point and the transactions costs generated by the rule govern the ability of the bargainers to move from the status quo point. Liability rules govern the distribution of burden between the so-called Pareto-relevant and Pareto-irrelevant externalities . . . and they govern the adjustment transactions and their allocative results. Change of the liability rule opens up new areas for the Pareto-domain, new avenues for transactions and consequent alterations in the allocation of resources.[30]

To conclude on the Coase theorem of allocative neutrality:

> [It] is not wrong; worse, it is severely incomplete and misleading yet with the appearance of final truth.[31]

Toward a Solution

The traditional remedy for combatting technological externalities centers around tax-subsidy schemes. But with the coming of Coase, his followers, and his critics, the belief that a single technique could be applied to all cases has been abandoned. Numerous possible solutions have been suggested in the literature but none would appear to be perfect, nor do any clearly dominate over all others in all cases.

Coase himself puts forth a "change of approach" centering around the premise that the inability to reach correct conclusions with respect to the treatment of externalities comes not from a "few slips" in the analysis, but from basic defects in the current approach to problems of welfare economics in general.[32] To begin with, the analysis has usually focused on some particular deficiency in the system, propagating the belief that any action which removes this deficiency is necessarily desirable. Coase cautions that this ignores the other consequent changes in the system which may well lead to more harm than the original deficiency. Instead the policy or decision-maker should appeal to the rationale underlying cost-benefit analysis: each course of action will have its associated costs and benefits; simply choose that action which produces the greatest net social benefits.

The second problem discussed by Coase centers

around the usual treatment in the analysis of conducting a comparison between a state of *laissez faire* and some kind of "ideal" world. One would be better advised to start the analysis with a situation approximating the actual and then examine the effects of alternative policies.

Coase's third reason for the failure of developing an adequate theory of externalities stems from what he refers to as the faulty concept of a factor of production. Coase would prefer to consider factors of production as "rights". The right to conduct some activity which may have adverse effects would also be classed as a factor of production. The cost of exercising a right, or using a factor, would be measured by the loss that is suffered elsewhere as a consequence of exercising that right. The social optimum would be that choice of rights that led to maximum net benefits.

It is relatively easy to deal with the efficiency aspects of a possible action, but to pick the "correct" point on the utility-possibility frontier one must consider the question of equity. That equity considerations are important has not been doubted, just ignored.

With these considerations in mind, it may prove illuminating to briefly consider the range of alternatives open to the relevant decision-maker given the presence of an externality. Broadly speaking there are three classes within the range: private motivation, governmental regulation, and economic or financial inducements.

Under the first class, private motivation, there is an incentive for either the producer or the recipient of the externality to initiate proceedings in the hope of reaching a mutually satisfactory agreement. Where bargaining is perfect, the resulting bribe or compensation, depending upon the prevailing liability rule, will supposedly lead to a Pareto optimal allocation of resources. But recall the fate of the Coasian theorem of allocative neutrality.

Another possible course of action under this first class would be a merger of the involved parties. Here the externality would be internalized, or at least, rendered Pareto irrelevant. The applicability of this solution is of course rather limited. The involved parties must necessarily be firms. Moreover, the possibility of effecting a merger depends crucially on the number of parties concerned. The more parties involved, the greater the difficulty of reaching mutually satisfactory terms of coalition. Given that the merger (or mergers) is undertaken, there still remains potentially enormous problems of effective coordination. One must also entertain the possibility that the merged entity may grow so large as to cause a distortion in the allocation of resources due to its new market power.

The case for public intervention into the allocation of resources often rests on the presumption that the costs of governmental action are relatively small in com-

parison to private transaction costs. Alternatively, equity considerations may provide such an incentive.

This leads into the second broad class, that of governmental regulation. Included here would be such policies as outright prohibition, setting limits or standards, zoning regulations, issuing licences, and prescribing protective or preventative devices. The common characteristic of this class of policies is the notion of legal sanctions in regulating specified actions. But one must also keep this fundamental point in mind: optimality in the treatment of externalities does not require their complete elimination, but rather, that the "correct" amount be removed. The crux of the matter lies in determining this "correct" amount.

> In principle the government can determine the social optimum . . . and ordain it. In practice it can do no such thing.[33]

In support of this claim, Dorfman and Dorfman[34] maintain that governmental efforts in this area are beset by a number of difficulties:

(1) inadequacy of information,

(2) crudeness of regulatory instruments,

(3) problems of enforcement, and

(4) haphazardness of burdens.

The first three are quite straightforward and require no further elaboration. The fourth warrants closer examination. It is concerned with the question of equity. The problem stems from the perverse relationship between inci-

dence of costs and benefits of governmental regulation--it would seem that "the incidence of the costs . . . is hard to foresee and still harder to rectify."[35]

Because government regulation fails to consider the market mechanism, it has been criticized as being arbitrary, and hence inefficient. This leads us into the third class of alternative actions, that of economic or financial inducements, where the user is left free to decide how best to respond to the inducement.

The variants in this class include subsidies, tax credits, taxes and effluent charges--their common characteristic being an emphasis on efficiency "by remanding a maximum amount of discretion to the individual user or polluter."[36] But these methods also have their shortcomings. Equity considerations are sometimes suppressed; tremendous amounts of information are required; there is often a problem of enforcement; plus, some have argued that effluent charges are nothing more than a "license to pollute".[37]

> Each case must be considered on its own and there is no *a priori* reason to suppose that the imposition of a tax is better than alternative measures or indeed, that any measures at all are desirable.
>
> To sum up, then: when negotiation is possible, the case for government intervention is one of justice not of economic efficiency; when it is not, the theorist should be silent and call in the applied economist.[38]

A Note on the Analysis

With the notable exception of the work of such authors as Ayres, Kneese and D'Arge,[39] the analysis of externalities has largely been conducted within a partial equilibrium framework:

> . . . a situation in which a single industry produces an equilibrium output, usually under conditions of perfect competition, some form of intervention being required in order to induce the industry to produce an "ideal" or "optimal" output. If the point is not made explicitly, it is tacitly understood that unless the rest of the economy remains organized in conformity with optimum conditions, one runs smack into second-best problems.[40]

This treatment would seem to reflect the tendency of the literature to consider externalities as rather exceptional phenomena, which can be dealt with adequately through some ad hoc arrangement. However, as Ayres and Kneese point out, externalities are an inevitable part of the consumption and production processes and their economic significance grows rapidly as economic development progresses (being reflected in large measure by the exhaustion of the natural assimilative capacities of the environment). Yet "final consumption" is looked upon as an end, as if these "consumed" goods or residuals completely disappeared into some void without a trace. Following the "materials balance approach", the actual level of residuals involves a greater tonnage than basic materials processing.[41]

So while a partial equilibrium approach may be both theoretically and empirically appealing, it neglects

the much broader interdependencies of the economy. Also included in this negligence is the treatment of pollution of particular environmental media as separable problems. As Ayres and Kneese note, there are important trade-offs between the forms (gaseous, liquid, or solid) that the residuals may take. Moreover, one must keep in mind that the waste assimilative capacity of the environment is limited, and as such should be considered as an important resource of increasing value.

Unfortunately the formal mathematical framework of the "materials balance" model is not an end-all to the problem. For while the model comes much closer to recognizing the total magnitude of the problem than a partial equilibrium approach, it poses a central planning problem of near impossible dimensions. Ayres and Kneese are quite aware of this difficulty. What the authors wish to convey is a warning--a warning that while a partial equilibrium approach is more tractable, it can be seriously misleading.[42]

The rationale of a general equilibrium approach to the environmental problems associated with tar sands development underlies the models of the next two chapters. In fact, materials balance calculations would make up a good portion of the regional residuals management model presented in Chapter IV.

The present chapter attempted to lay out the theoretical basis of the externality problem and briefly

alluded to some of the possible policy options before decision makers. The following chapters, for the most part, take these considerations for granted, and concentrate on the goals of such policies.

Footnotes

[1]J. M. Buchanan and W. C. Stubblebine, "Externality", reprinted in *Readings in Welfare Economics*, ed. K. A. Arrow & T. Scitovsky (Homewood: Richard D. Irwin, 1969), p. 199.

[2]E. J. Mishan, "Reflections on Recent Developments in the Concept of External Effects", *Canadian Journal of Economics and Political Science* (February 1965), pp. 4-5.

[3]W. J. Baumol and W. E. Oats, *The Theory of Environmental Policy* (Englewood Cliffs: Prentice-Hall, 1975), p. 17.

[4]See Buchanan and Stubblebine, "Externality", for a detailed mathematical discussion of the concept. In particular, the authors claim that a marginal externality exists when, after taking partial derivatives,

$$U^A_{Y_1} \neq 0.$$

If the expression is positive (negative), then we have a marginal external economy (diseconomy) where a small change in the activity undertaken by B results in a change of A's utility in the same (opposite) direction. If

$$U^A_{Y_1} = 0 \text{ but } U^A = U^A(X_1, X_2, \ldots, X_m, Y_1)$$

holds, then an inframarginal externality exists. In other words, while incremental changes in the extent of B's activity, Y_1, do not affect A's utility, the total effect of B's action has changed A's utility.

[5]Baumol and Oates, *The Theory of Environmental Policy*, p. 18.

[6]Buchanan and Stubblebine, "Externality", claim that an externality is "potentially relevant" when ". . . the activity, to the extent that it is actually performed, generates any desire on the part of the externally benefited (damaged) party (A) to modify the behavior of the party empowered to take action (B) through trade, persuasion, compromise, agreement, convention, collective action, etc. An externality which, to the extent that it is performed, exerts no such influence is defined as irrelevant." An externality is said to be "Pareto relevant" when the extent of the activity can be modified in such a way that the externally affected party, A, can be made better off without the acting party, B, being made worse off. (pp. 201-202).

[7]See A. K. Dasgupta and D. W. Pearce, *Cost-Benefit Analysis: Theory and Practice* (London: Macmillan, 1972), pp. 120-121; and Baumol and Oates, *The Theory of Environmental Policy*, pp. 28-30.

[8]E. J. Mishan, "The Postwar Literature on Externalities: An Interpretative Essay", *Journal of Economic Literature* (March 1971), p. 6. Dasgupta and Pearce, *Cost-Benefit Analysis*, bring out an in-

teresting point between pecuniary externalities and cost-benefit analysis. Because these effects reflect only transfers, some would argue that they are not relevant to a cost-benefit appraisal. However if the social welfare function used in cost-benefit contained explicit distributional weights, then pecuniary effects would be very relevant, for in this case, the incidence of the transfers would matter. (p. 121).

[9]J. M. Buchanan, "The Coase Theorem and the Theory of the State", *Natural Resources Journal* 13 (October 1973), p. 579. Buchanan is referring to the article by R. H. Coase, "The Problem of Social Cost," reprinted in *Economics of the Environment*, ed. R. Dorfman and N. S. Dorfman (New York: W. W. Norton, 1972), pp. 100-129.

[10]Coase, "The Problem of Social Cost," p. 101.

[11]R. Turvey, "On Divergences between Social Cost and Private Cost", reprinted in *Economics of the Environment*, ed. Dorfman and Dorfman, pp. 130-134.

[12]*Ibid*, p. 131.

[13]A. Randall, "Coasian Externality Theory in a Policy Context", *Natural Resources Journal* 14 (January 1974), p. 41.

[14]Buchanan, "The Coase Theorem", p. 580.

[15]Randall, "Coasian Externality Theory", p. 53.

[16]W. J. Samuels, "The Coase Theorem and the Study of Law and Economics", *Natural Resources Journal* 14 (January 1974), p. 1.

[17]Randall, "Coasian Externality Theory", pp. 42-43.

[18]F. T. Dolbear, "On the Theory of Optimum Externality", *American Economic Review* (March 1967), pp. 90-103.

[19]J. F. Due and A. F. Friedlaender, *Government Finance Economics of the Public Sector* (Homewood: Richard D. Irwin, 1973), pp. 86-89. Their analysis is based on the work of J. R. Hicks, *A Revision of Demand Theory* (Oxford: Oxford University Press, 1969).

[20]*Ibid*, p. 87. See also Mishan, "The Postwar Literature", pp. 18-21, for similar arguments. Mishan concludes ". . . for significant environmental spillovers, the arrangement that is optimal under one state of the law is not optimal under the other state of the law." (p. 20).

[21]Samuels, "The Coase Theorem and the Study of Law and Economics", p. 2.

[22]*Ibid.*

[23]*Ibid*, pp. 2-3.

[24]*Ibid*, p. 8.

[25]Mishan, "The Postwar Literature", p. 21.

[26]This would include such matters as identifying the members of the group, persuading them to make, or accept, some joint offer, and negotiate with the other group. *Ibid.*

[27]An example of this relocation solution might be where the firm moves to an area where little or no other industrial activity is undertaken. In such an area, perhaps the assimilative capacity of the environment can render the "pollution" harmless.

[28]Randall, "Coasian Externality Theory", p. 44.

[29]R. C. D'Arge, "Coase Theorem Symposium: Introduction", *Natural Resources Journal* 13 (October 1973), pp. 559-560.

[30]Samuels, "The Coase Theorem and the Study of Law and Economics", p. 20.

[31]*Ibid*, p. 31.

[32]See Coase, "The Problem of Social Cost", pp. 127-129.

[33]Dorfman and Dorfman, *Economics of the Environment*, p. xxxvi.

[34]*Ibid.*

[35]*Ibid*, p. xxxvii.

[36]*Ibid*, p. xxxviii.

[37]D. N. Thompson, *The Economics of Environmental Protection* (Cambridge: Winthrop Publishers, 1973), p. 184.

[38]Turvey, "On Divergences between Social Cost and Private Cost", p. 134.

[39]R. U. Ayres and A. V. Kneese, "Production, Consumption and Externalities", *American Economic Review* (June 1969), pp. 282-297; and A. V. Kneese, R. U. Ayres and R. C. D'Arge, *Economics and the Environment: A Materials Balance Approach* (Baltimore: Johns Hopkins Press, 1970).

[40]Mishan, "Reflections on Recent Developments". If these optimum conditions are not met in the rest of society, then there is no certainty that the output meeting the optimal conditions in the sector undergoing adjustment will move the economy, taken as a whole, closer to the Pareto optimum.

[41]For the amount of residuals must be approximately the same as the weight of basic fuels, food, and raw materials entering the processing and productive system plus oxygen taken from the atmosphere. Ayres and Kneese, "Production, Consumption and Externalities", pp. 284-285.

[42]*Ibid*, pp. 295-296.

CHAPTER III

CONSIDERATIONS PERTINENT TO RECLAMATION DECISIONS

The development of the Athabasca tar sands is an enormous and extremely complex undertaking. The "social" economics of the situation dictate that all aspects and impacts of development be rigorously identified and evaluated. One of these aspects concerns the potential environmental effects. To fully discern the possible magnitude of these effects, a comprehensive environmental impact assessment is essential. Such an assessment must take account of all short- and long-term effects attributable to human actions on the physical and biological environments of the tar sands area.

This chapter and the next will attempt to consider some of the environmental implications of tar sands development. The present chapter will deal primarily with the economic considerations pertaining to reclamation of the disturbed areas. The criterion used to determine the optimum level of reclamation will be one of maximizing social welfare, or net social benefits, through benefit-cost analysis. Chapter IV will complement this line of

thought but will be much more encompassing in scope and technique--indeed, it will be argued that a regional residuals management model of a multidisciplinary nature is essential if one is seriously contemplating the social welfare optimum with respect to development of the tar sands.

The Magnitude of the Problem

The Athabasca tar sands occupy an area of some 11,340 square miles. Of this area, approximately one-half million acres (800 square miles) have an overburden depth of less than 200 feet. The bitumen within these deposits will probably be recovered through surface mining techniques. Based on a projected level of activity of one million barrels per day (approximately eight Syncrude-sized plants), Intercontinental Engineering of Alberta Limited (Integ) estimated that roughly six acres of land, on average, would be disturbed daily by mining operations.[1] The denuded area would approach 22,000 acres (34 square miles) before a balance between newly disturbed and reclaimed land could be reached. At this level of activity, some 700 million tons of tar sand would be mined per year (see Table III-1), and fresh water requirements would approach 350 cubic feet per second (or 10 per cent of the minimum monthly average flow of the Athabasca River).[2]

TABLE III-1

UNIT RATIOS FOR TAR SANDS/BITUMEN/PRODUCTS

	Units*	GCOS	Syncrude	Total**
Tar Sand Mined	TPCD	140,000	225,000	1.9 million
Bitumen Recovered	BPCD	85,000	140,000	1.25 million
Synthetic Crude Oil Produced	BPCD	65,000	125,000	1.0 million
Calculated Unit Ratios:				
Barrels Bitumen Recovered Per Ton Tar Sands		.61	.62	.65
Barrels Product Per Barrel Bitumen		.76	.89	.80
Barrels Product Per Ton Tar Sands		.46	.55	.53

* TPCD: Tons per calendar day; BPCD: Barrels per calendar day.
** Total based on projected level of activity of eight Syncrude-sized plants.

Source: "The Integ Report," p. 15.

As noted by the Conservation and Utilization Committee's Task Force on Hydrological Research, discussions on environmental constraints and the degree of success of reclamation are " . . . ultimately and inevitably led back to one key issue--the nature and disposition of the tailings and plant effluents."[3] Given that it is on these waste solids and liquids that the future flora and fauna are to be established, it becomes imperative that the chemical and physical properties of these residuals be understood if reclamation attempts are to prove successful.

With its projected level of activity of 1 million barrels per day, Integ estimated that a total of 42 million cubic feet of tailings will be pumped into the ponds every day.[4] Sand, silt, and clay will account for 65 to

70 per cent of the tailings slurry, water 30 to 35 per cent, and unrecovered bitumen, 0.5 to 1.2 per cent.[5] Table III-2 shows the proposed size and location of the tailings ponds. Tables III-3 and III-4 refer solely to the Syncrude operation and its proposed tailings ponds.

TABLE III-2

PROPOSED SIZE AND LOCATION OF TAILINGS PONDS

Location of Pond	Size of Pond
GCOS	470 acres (.73 square miles)
Syncrude Canada Ltd.	7,360 acres (11.5 square miles)
Shell	3,860 acres (6.0 square miles)
Petrofina *et al.*	2,400 acres (3.8 square miles)
Home-Alminex	4,160 acres (6.5 square miles)
Total	18,250 acres (28.5 square miles)

Source: Environment Conservation Authority, "Review of Interaction Between Migratory Birds and Athabasca Oil Sands Tailings Ponds: Report and Recommendations," 1975.

TABLE III-3

MATERIAL DATA (SYNCRUDE OPERATION)

Tar Sand Mining Rate		92,800,000 T/yr.
Bitumen Production Rate		125,000 BPCD
Tailings from Extraction Plant		
Sand	62,000,000 T/yr.	
Silts and Clays	9,500,000 T/yr.	
Water	71,500,000 T/yr.	
	143,000,000 T/yr.	143,000,000 T/yr.
Tailings from Froth Treatment Plant		
Sand	1,300,000 T/yr.	
Silts and Clays	300,000 T/yr.	
Water	5,600,000 T/yr.	
	7,200,000 T/yr.	7,200,000 T/yr.
Sour Water from Naptha Recovery and Waste Waters from the Upgrading Units		220,000,000 CF/yr.
Ground Water* from the Mine Pit		281,000,000 CF/yr.

(Continued)

(Table III-3, continued)

* Possibly saline.

Units: T/yr = tons per year; CF/yr. = cubic feet per year.

Source: Syncrude Canada Ltd., "Environmental Impact Assessment," Vol. IV.

TABLE III-4

SYNCRUDE'S TAILINGS POND
(AT TERMINATION OF THE INITIAL 25-YEAR OPERATION)

Free Water	2,720,000,000 CF
Sludge (@ 30% solids)	10,540,000,000 CF
Coarse Sands (@ 78% solids)	6,370,000,000 CF
Total Volume	19,630,000,000 CF

Source: Syncrude Canada Ltd., "Environmental Impact Assessment," Vol. IV.

Conceptual Limitations and Qualifications

Given the magnitude of the strip-mining operations, and the huge volumes of tailings, the potential for environmental damage and degradation would appear to be quite large. In fact, The Conservation and Utilization Committee, in its proposed development strategy, claimed that the "basic impact" on the environment would amount to

> . . . partial to total denudation of the surface vegetation, partially disrupted to totally obliterated surface hydrology, extensive changes to the groundwater regime caused by increasing injections and recharge capability modified by a vastly increased permeability rate of the bituminous depleted sands, altered topographical landforms caused by the deposition of spent tailings or the subsidence of depleted sands, massive withdrawals

> of surface water from streams and rivers causing physical changes to their stream flow characteristics, heated effluent waters resulting in chemical and biological changes to the receiving waters and atmospheric changes such as ice fog during the winter, atmospheric gaseous emissions containing sulphur dioxide and other compounds, all of which will have disruptive effects on the remaining flora and fauna because of the massive ecological changes. In addition, there will be those environmental changes caused by the numerous transportation and communication networks as well as the growth of Fort McMurray and other townsites and the effect of these increasing populations and their accessibility to the surrounding environs.[6]

As yet, however, little or no effort has been devoted to subjecting these problems, in whole or in part, to economic analysis. We can safely assume that the tar sands operators will attempt to maximize their profits. Attempts to maximize private profits, however, are not sufficient to guarantee maximum social welfare. On the contrary, market failure, which precludes the possibility of maximizing social welfare in the absence of corrective actions, results whenever there is a divergence between private and social costs. And if the tar sands operators are successful in their attempts to minimize their private costs, i.e. maximize their profits, some costs may be passed on to others. We will have a misallocation of resources, a problem of equity, and justification for government intervention.

This is not meant to imply that our economic and ecological systems are incompatible with one another.[7] The competitive economy rewards those producers who can

supply at least cost. This is compatible with environmental protection providing that all resource costs are reflected in the costs and prices of the bitumen extracted. Even if the operators are forced to account for all their costs, we still may fall short of our social optimum if cheaper solutions to some problems are not available to one or more of the operators. For if we are to capture all the relevant economies of scale, a regional approach, as opposed to a lease by lease approach, may be necessary. External costs and economies of scale are the two most important rationales for government intervention.[8]

Another qualification deserves mention at this time. We want the operator to include all costs in his calculations but this does not imply that all external effects are to be completely eliminated. Our objective is one of maximizing social welfare. To completely eliminate all external effects would be a very costly undertaking in terms of the use of society's scarce resources. And if we are to be guided by the principle of economic efficiency, ignoring equity considerations for the moment, then

> . . . society should continue to employ resources for the preservation and control of environmental impacts only up to the point where the value of the resources so employed just equals the value of external costs avoided.[9]

Thus, when attempting to ascertain the optimum level of reclamation, each additional unit of reclamation must be justified at the margin. The benefits and costs of re-

clamation will undoubtably vary across lease holdings. The question comes down to determining where, and in what amounts, should our scarce reclamation funds or resources be placed if we are to maximize net social benefits.

The analysis has proceeded thus far on the implicit assumption that once the benefits and costs associated with the strip-mining and reclamation operations have been identified that their estimation presents no problem. Where market prices exist, they can be directly incorporated into the analysis. Presumably the market cost of mining (which would include licensing fees, royalty payments and the like, payable to the provincial government as owner of the deposits) would reflect the time stream of expected net returns that the land would have yielded had it been employed in its next best use. With the tar sands area, the alternative uses would appear to be of relatively little importance owing largely to climatic and soil limitations. No agriculture is practised within the area, and hunting, trapping and fishing are conducted only to a limited extent. The potential for a commercial lumber or pulpwood industry would also appear to be limited at the present time.[10] It would seem, therefore, that the present value of the time stream of private net returns from strip-mining would be greater than the market price of this land for any alternative commercial use.

A question that should be raised is whether or

not the market price of the land adequately reflects the social value of all the alternative uses. For while the private monetary returns on alternative uses may be quite low for the area, the "market" may not have considered the social return on the scenic amenities, the natural habitats, or the genetic "banks". Indeed, given the public good nature of these uses, it is unlikely that they have been adequately considered by the market.[11] And it is quite conceivable that many people would be willing to pay some amount for the preservation of the scenic amenities and natural habitats even though they realize that they may never visit the area.[12]

The environment can be viewed as a "natural asset" or as a kind of "nonreproducible capital good" which provides a stream of services to man.[13] This stream consists of a flow of material inputs, waste receptor capabilities, amenity services and, of course, life sustaining functions. These services are by no means wholly independent of one another in terms of either quality or quantity. The greater the demand and use of the waste receptor capabilities, the lower the flow of the other services. In effect, we can define the willingness to pay for the nonwaste receptor services as the demand for, or the benefits of, environmental quality.[14] And in this light, pollution can be thought of as a reduction in environmental quality due to the disposal of residuals or the destruction of natural habitats or scenic amenities.

In the present context, the strip-mining operations will infringe upon both the quantity and quality of the nonwaste receptor services. With appropriate reclamation procedures, these external costs can be reduced substantially.[15] It would seem that the main benefit derived from reclamation comes down to the avoidance of external costs. What must be decided is whether the benefits from preventing these external costs are greater than the costs of reclamation or the costs that would be suffered elsewhere as a result of halting the activity which produced the harm. This is not an "either-or" situation; rather, it is one of degree--the problem is to determine the optimum level of strip-mining and the optimum level of reclamation.

The Model[16]

Reclamation is a rather loose term denoting a variety of methods for improving upon the state of the residual material that will remain after the oil is separated from the sand. At the one extreme, reclamation would refer to careful grading and contouring of the land and replacement of the topsoil or muskeg in a manner such that no one would be aware that any mining operations had taken place.

> Unfortunately, however, the term's coinage has been devalued by operators who throw a few grains of annual rye at a pile of grey slag and then depart alleging that they have "reclaimed" the land. As Senator Nelson des-

> cribed it, some reclamation "is really a kind of green lie. When you look at it closely it is crabgrass and quack grass and brush . . . ."[17]

The available information on the costs of reclamation efforts is both scarce and vague.[18] Often it is difficult to determine if these efforts were restricted to the simple leveling of the land or encompassed more elaborate schemes of total revegetation. Moreover, the reported figures refer to land reclamation of coal mining areas. Even for this type of mining the estimated costs vary considerably depending upon the nature of the terrain and the ultimate use for which the land is being reclaimed. In 1966, Brooks found that grading costs alone ranged from 1¼ cents per ton to 43 cents.[19] On a "per acre" basis, the reclamation costs varied from $50 to $3,000. The latter figure pertained to "restoring" a mountainous area to its original contour and forest cover. The $50 figure, on the other hand, referred to reasonably flat terrain and normally included little grading, minor soil preparation and erosion control, and the planting of tree seedlings. Given a rougher terrain, the $50 might only ensure correct drainage systems. (With strip-mining in the tar sands area, the residuals will occupy up to a 30 per cent greater volume than the void created by the mining operations; hence, the final elevation of the reclaimed areas may be some 100 feet higher than the surrounding terrain, and could pose problems for both contouring and drainage.[20])

Brooks was led to believe that the $50 per acre would only circumvent the worst effects of coal strip-mining, and should not be thought of as an average cost of reclamation.[21] Figures in and around $250 per acre were more to his liking with respect to reforestation and pollution control on relatively level terrain.

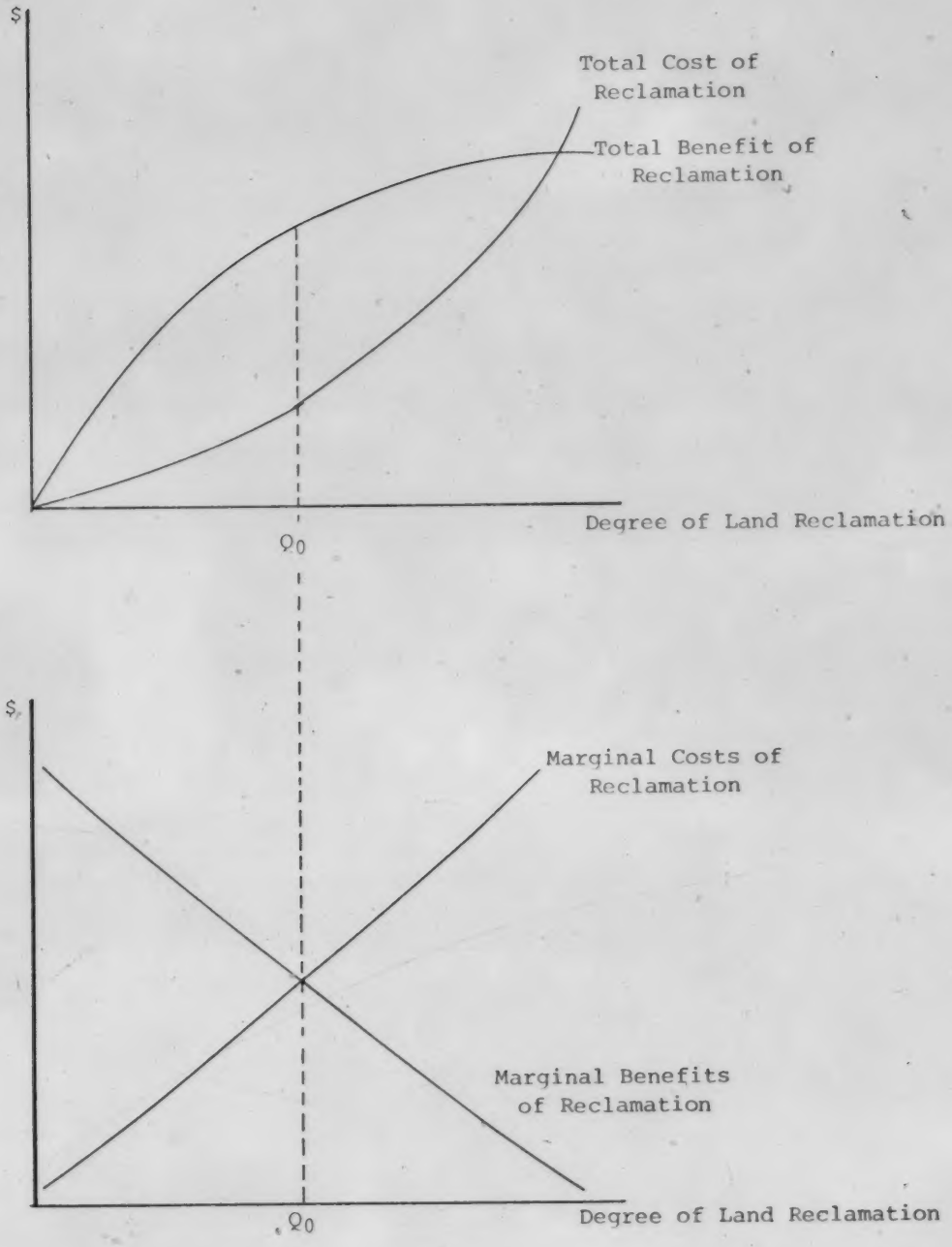
Turning to reclamation efforts with respect to coal strip-mining in Alberta, current estimates vary from $200 to $2,000 per acre.[22] If we apply these estimates to the tar sands, and given Integ's projections of eight Syncrude-sized plants disturbing 2,200 acres of land a year, the costs of reclamation would range from $440,000 to $4,400,000 per year, or from 0.12¢ to 1.2¢ a barrel.[23]

With respect to the oil sands, these figures are at best a rough approximation, and only in the relative sense. That is, we would expect, as in the case of coal mining, that the costs of reclamation would increase, and at an increasing rate, as we attempt to move toward greater and greater levels of reclamation. The benefits of reclamation, however, as determined by the willingness to pay for environmental quality, would also increase, but at a decreasing rate, as we moved to higher levels of reclamation. (See Figure III-1.)

Associated with the total benefit and total cost curves are the marginal curves, as shown in the lower portion of Figure III-1. The optimum level or degree of reclamation occurs where the difference between the total

FIGURE III-1

BENEFITS AND COSTS OF RECLAMATION

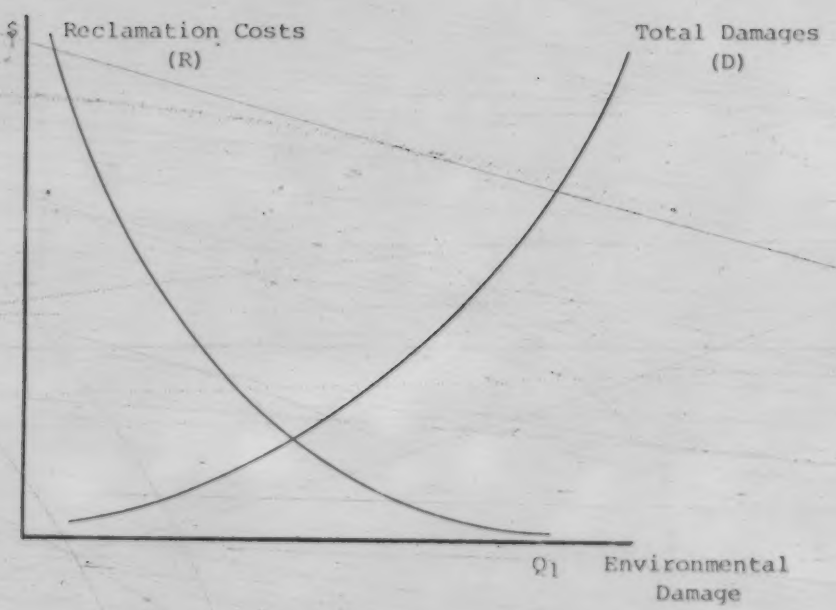


benefits of reclamation and the total costs of reclamation is at a maximum. In marginal terms, as long as the benefits derived from another unit of reclamation exceed the costs of attaining that unit, then we should undertake that unit increase in reclamation. Eventually, a point will be reached where a further unit increase in reclamation would add more to cost than benefit. Hence, the optimum degree of reclamation is where the marginal benefit derived from the last unit of reclamation just equals the cost of obtaining that unit. In terms of Figure III-1, the optimum is given by Q_0.

Alternatively, we can derive our optimum by measuring how much members of society would be willing to pay in order to avoid environmental damage. In terms of Figure III-2, as we move outward along the horizontal axis, we would experience increasing amounts of environmental damage due to strip-mining operations (the origin, therefore, would represent the natural, or original, level of environmental quality). As we move in this direction, we would expect that the willingness to pay to avoid these damages would increase, at an increasing rate, and hence, the positive slope of the total damages function (D).[24] Moving in the opposite direction, as we attempt to restore the environment to its previous quality level prior to the commencement of the stripping operations, we would expect that the costs of reclamation would increase and at an increasing rate once diminishing returns set in. Given

FIGURE III-2

DAMAGE AND TREATMENT COSTS FOR ENVIRONMENTAL QUALITY



some level of activity and no expenditures on reclamation, we would have a point such as Q_1 on the horizontal axis. As we attempt to restore the quality of the environment, greater and greater expenditures on reclamation would be necessary, leaving us with the negatively sloped reclamation cost curve (R).

Given some level of strip-mining activity, the optimum level of environmental damage would be at that point where the total costs of strip-mining damage are at a minimum. By vertical summation of the total damage

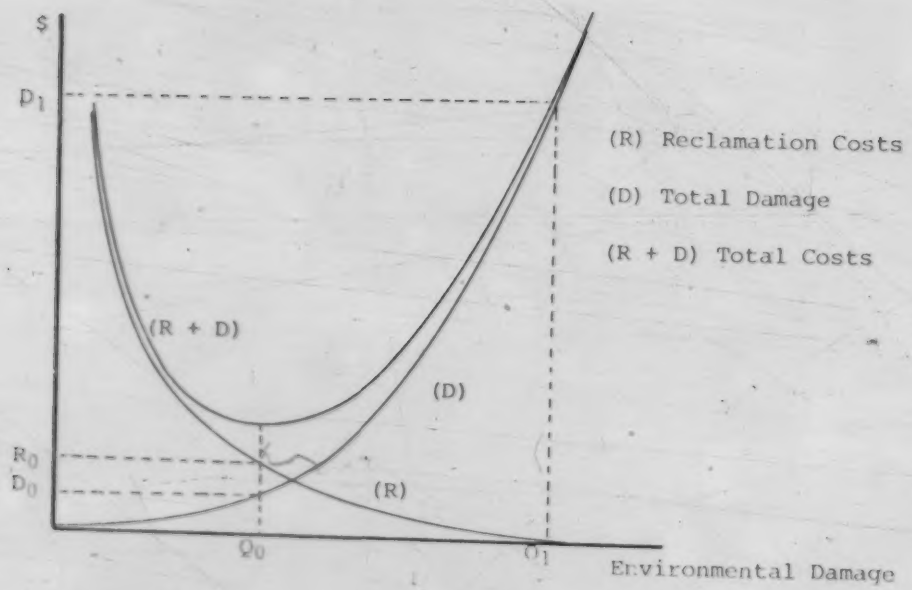
curve (D) and the reclamation cost curve (R), we can construct a total cost curve (D + R). The minimum point on this curve would give us the optimum level of environmental damage. In Figure III-3, the minimum is given by point Q_0. Hence, given some level of activity which would result in environmental damage of, say, Q_1, at a cost of D_1, we should undertake reclamation expenditures equal to R_0 and reduce damages from D_1 to D_0.

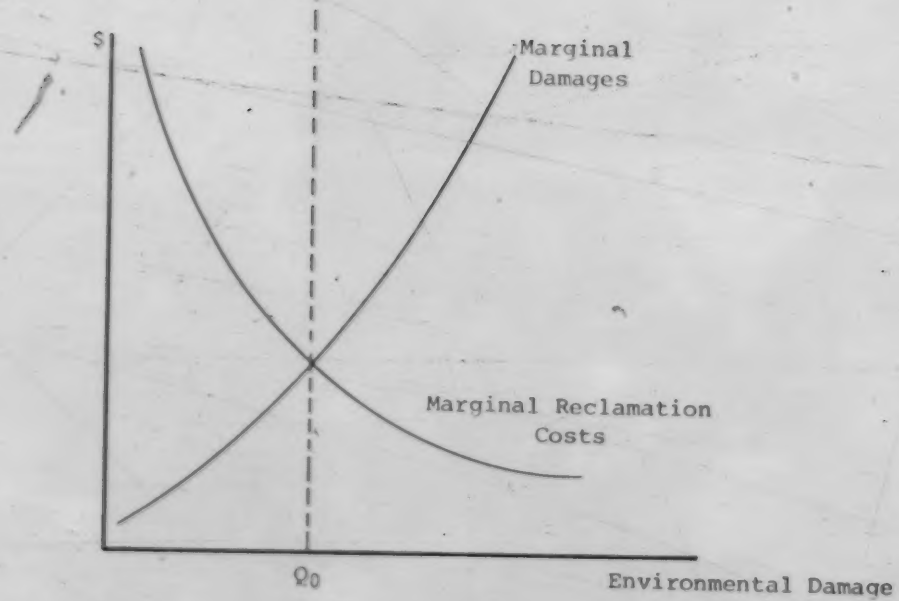
As before, we could have reached the same optimum through marginal analysis. The marginal curves corresponding to the reclamation cost curve (R) and the total damage curve (D) are given in the lower portion of Figure III-3. Again, the optimum is reached when the marginal cost of the last unit of reclamation just equals the marginal benefit derived from that unit, which in the present case is equal to the marginal damages foregone. To continue reclamation expenditures past this point would add more to cost than to damages foregone.[25] In terms of Figure III-3, the optimum level of environmental damage is given by point Q_0.

The analysis so far has proceeded on the assumption that we are given some level of strip-mining activity, i.e., so many acres "disturbed". Once given this activity level, we have attempted to determine the optimum level or degree of reclamation. Clearly this is an "ex post" approach to the problem. Apart from GCOS, the operators have not started their stripping operations.

FIGURE III-3

THE OPTIMUM LEVEL OF ENVIRONMENTAL DAMAGE





Hence, the level of activity should be a variable in our analysis, providing us with greater flexibility in attempting to maximize social welfare.

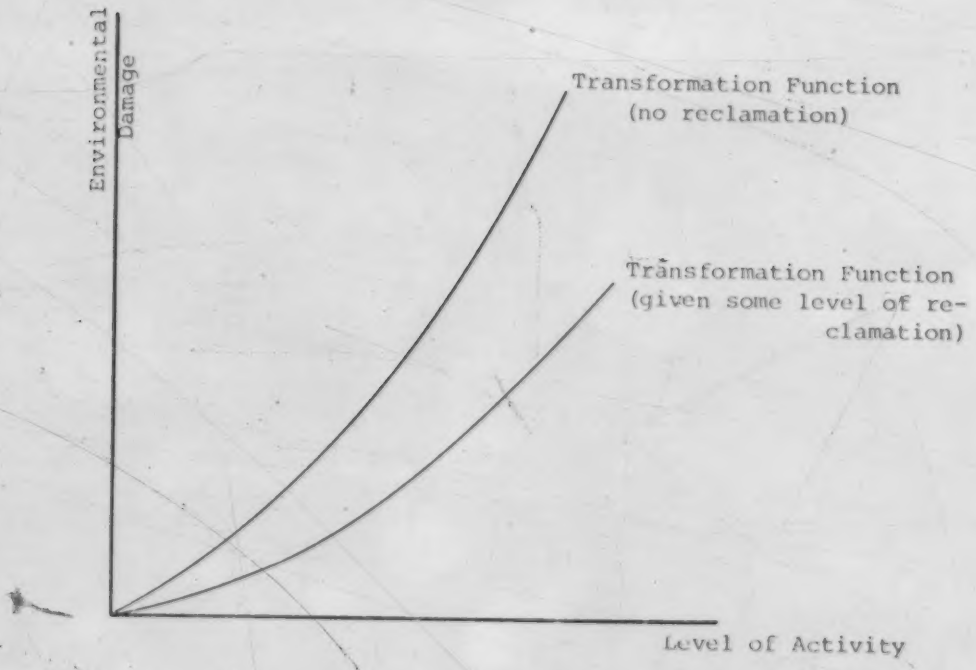
In effect, what we want to determine is the relationship between various levels of activity and their corresponding levels of environmental damage. These relationships are quite complex and depend upon a myriad of environmental parameters, some of which fluctuate through wide margins in relatively short periods of time (such as temperature and wind speed). The relationship between the level of activity and its associated level of environmental damage is known as a transformation function.[26] Successful reclamation procedures would reduce the damage associated with any given activity level. (See Figure III-4.)

Given the objective of maximizing net social benefits, it would seem that we must approach the problem through a regional context. That is, we would like to estimate the total social benefits and social costs associated with varying activity levels, i.e. differing numbers of operators and differing scales of operation for each. Following the line of analysis put forth in the first part of this section, we can set out to determine the optimum level of activity, the optimum degree of reclamation and the optimum level of environmental damage.

As we increase the level of activity we would expect the total social benefits to increase, but at a

FIGURE III-4

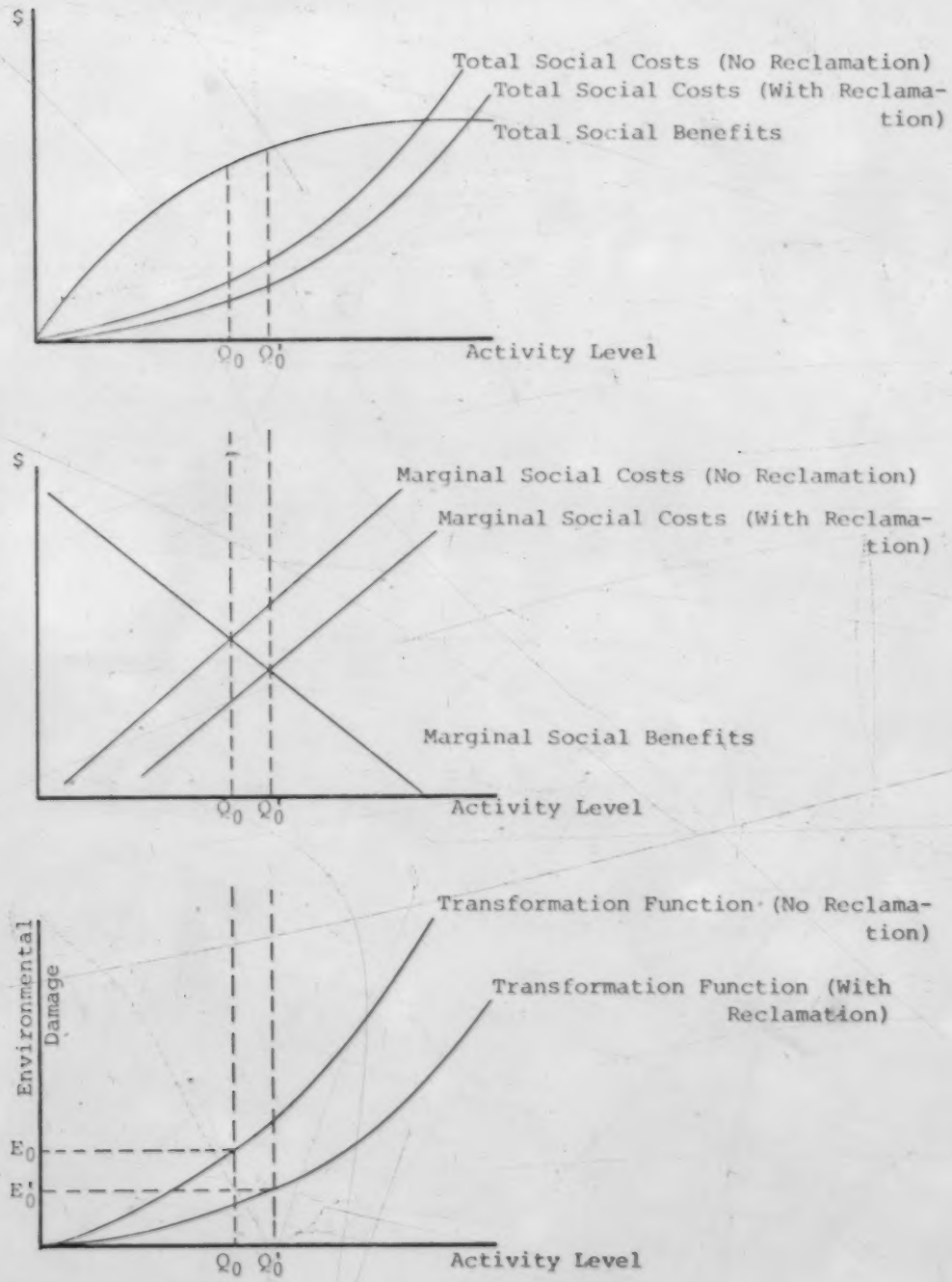
THE TRANSFORMATION FUNCTION


Environmental Damage
Transformation Function (no reclamation)
Transformation Function (given some level of reclamation)
Level of Activity

decreasing rate as we expand into less productive leases.[27] The total social costs would also increase, and at an increasing rate, owing to such things as higher extraction costs in leaner deposits, input bottlenecks, and growing external costs. To maximize net social benefits (ignoring the benefits derived from reclamation for the moment) we should operate at that level of activity that maximizes the difference between total social benefits and social costs (see the top diagram in Figure III-5), or, in other words, where the marginal social benefits just equal the marginal social costs (middle diagram in Fi-

FIGURE III-5

THE OPTIMUM LEVELS OF ACTIVITY, RECLAMATION AND ENVIRONMENTAL DAMAGE



gure III-5). This optimum, which ignored the possibility of benefits derived from reclamation efforts, is given by point Q_0. The associated level of environmental damage is given by the transformation function (point E_0 in the lower diagram in Figure III-5). This too would be an optimum given that all social costs and social benefits were used in establishing the optimum level of activity.

Now let us introduce the possibility of reclamation into the analysis. As mentioned earlier, it would seem that the main benefit derived from reclamation is in the avoidance of external costs. Therefore, if reclamation attempts prove "successful", not only would the transformation curve shift down for all levels of activity, but the total social cost curve (and the associated marginal social cost curve) would also be affected. As the amount of resources put into reclamation efforts increases, private costs would rise. However, if reclamation efforts are to be classed as successful, the external costs or damages avoided must exceed the private costs incurred. If such is the case, the total social cost curve will shift downward. Reclamation efforts should be continued until the damages foregone just equal the private costs incurred to bring about this last unit of reclamation. Once we have reached this point, the total social cost curve can not shift down any further. In fact, to expand reclamation efforts past this point would add more to private costs than it would to damages foregone, and hence, would force

the curves to shift upwards. (Given the shapes of the curves in Figure III-5, and their respective shifts, the new optimum level of activity is given by point Q_0' with associated environmental damages of E_0'.)

Concluding Comments

Given the magnitude of the tar sands development, it is readily apparent that formidable difficulties will be encountered when attempting to implement the model. In particular, it is the social benefits and costs upon which we hope to base our decisions. The desired measure of benefit is society's willingness to pay. To impute these values, we rely on the "market". The market, as such, does not exist for the valuation of all the goods and services that will be affected by development. Other methods and procedures must be developed to determine the demand for, and the dollar value of, scenic amenities, genetic "banks", natural habitats and the like.[28] Estimation problems exist, and they will take much time, effort, and money to rectify. But given the costs--or potential costs--involved, the research money should be forthcoming. Within Canada, or even Alberta for that matter, the people and the facilities are available to supply the effort. And it would seem that the natural forces of the market are providing the time. The fears of OPEC embargoes, and rapid and large price hikes have been all but forgotten; the potential tar sands operators would seem to be content

to wait on the success of Syncrude, on frontier explorations, and on the world energy situation in general. Hence, we do have the time, effort, and money necessary to conduct the research. Again, at the risk of sounding redundant, we must approach these problems from a regional point of view. This will not guarantee that we will maximize net social benefits, but it will give us a better chance of doing so than afforded by the piecemeal strategies presently pursued by the provincial and federal authorities.[29]

A further dimension, centering on the differential impact of technological progress over time, deserves mention.[30] The bitumen from the tar sands is to serve as a feedstock or input into some petrochemical installation. Increases in demand for this input can be met by stepping up production within the tar sands area, and/or by turning to one or more of the substitute sources. Technology is subject to change and may disturb the relative prices between the bitumen and its substitutes. Some authors would argue, in fact, that the benefits from a development such as the tar sands would decrease through time.[31] Assuming that the tar sands operators are profit maximizers, they would develop their respective lease holdings only if the net benefits derived from such an undertaking were greater than those derived from their next best alternative. The gross benefits from either project would be equal, i.e. provide an equal amount of

energy, but the costs--and hence the net benefits--may be quite different. Over the long run, however, the costs of the next best alternative (be it another source of oil or another form of energy) will decrease given improvements in technology. In this case, the net benefits of the tar sands project, as determined by the difference in costs between it and its next best alternative, would be decreasing through time.

While the benefits derived from development may be decreasing through time, the opposite is true with respect to the preservation of natural environments. The services provided by the environment have no close substitutes and are "nonproducible", leaving supply fixed and technical advance meaningless. Through time, the demand for wilderness recreation, one of the services provided by the environment, is growing rapidly.[32] This increases the value of the services and, hence, the value of the preserved land. Consequently, development of the lease holdings can have a "dynamic opportunity cost" which grows over time.[33] And given the public good nature of the environmental services, the market fails to provide an optimal amount of preserved environments, and the optimal amount would seem to be increasing over time.

Footnotes

[1]Intercontinental Engineering of Alberta Limited, "An Environmental Study of the Athabasca Tar Sands", Alberta, 1973, p. 61 (hereafter referred to as The Integ Report).

[2]*Ibid.*, p. 71.

[3]The Conservation and Utilization Committee Oil Sands Hydrological Research Task Force, "Alberta Oil Sands Hydrological Research", Alberta, 1974, pp. 2-3.

[4]The Integ Report, p. 73.

[5]See The Conservation and Utilization Committee Oil Sands Reclamation Research Task Force, "Alberta Oil Sands Reclamation Research", Alberta, 1974, pp. 9-10.

[6]The Conservation and Utilization Committee, "Fort McMurray Athabasca Tar Sands Development Strategy", Edmonton, 1972, pp. 53-54. For a discussion of the various environmental problems, see The Integ Report; and H. W. Thiessen, "The Impact of Oil Sands Development on the Land Surface", address to the Engineering Institute of Canada Western Region Tar Sands Conference, Edmonton, April 1974.

[7]This idea of compatibility between our economic and ecological systems is developed in R.C.B. Morton, "Strip Mining Reform--Some Political and Economic Ideas", *Environmental Affairs* 2 (Fall 1972): pp. 294-302.

[8]See D. B. Brooks, "Strip Mine Reclamation and Economic Analysis", *Natural Resources Journal* 6 (January 1966): pp. 32-33.

[9]R. L. Spore, "The Economic Problem of Coal Surface Mining", *Environmental Affairs* 2 (Spring 1973): p. 686.

[10]The estimated sustained potential fur yield for the entire area is less than $375,000 per year, while the annual quota of allowable cutting on a sustained yield basis amounts to $1.6 million per year. The Integ Report, pp. 43 and 47.

[11]Public goods are those goods or services that are jointly supplied to society as a whole in the sense that benefits accrue collectively to society. Private enterprise has no incentive to produce these goods, or take account of them, for they have no means of selling them to individuals--once produced, no one can be denied their benefits. See J. F. Due and A. F. Friedlaender, *Government Finance Economics of the Public Sector* (Homewood: Richard D. Irwin, 1973), Chapter 3.

[12]The idea presented here centers around the idea of "option" value or "option" demand. For a discussion of this concept,

see J. V. Krutilla, "Conservation Reconsidered", *American Economic Review* 57 (September 1967): pp. 777-786; and J. V. Krutilla and A. C. Fisher, *The Economics of Natural Environments* (Baltimore: Johns Hopkins University Press, 1975).

[13]For a brief discussion of these services that the environment has to offer, see A. M. Freeman, R. H. Haveman, and A. V. Kneese, *The Economics of Environmental Policy* (New York: John Wiley & Sons, 1973), pp. 19-24.

[14]Rather than deriving the "willingness to pay" to ascertain the value of these services, "compensation" could provide an alternative measure. The former measures the maximum sum a person would be willing to pay to ensure that some beneficial change occurs; the latter measures the minimum sum a person would require as compensation to consent to a detrimental change; and the two may not give rise to the same value. See Due and Friedlaender, *Government Finance*, pp. 86-89.

[15]For an interesting discussion on "artificial restoration and the significance of authenticity", see Krutilla and Fisher, *Natural Environments*, pp. 45-47.

[16]The model presented here is an adaptation of the one put forth by Freeman, Haveman and Kneese, *Environmental Policy*, pp. 83-91.

[17]F. P. Bosselman, "The Control of Surface Mining: An Exercise in Creative Federalism", *Natural Resources Journal* 9 (April 1969): p. 146.

[18]With the possible exceptions of S. M. Brock and D. B. Brooks, *The Myles Job Mine--A Study of Benefits and Costs of Surface Mining for Coal in Northern West Virginia* (Office of Research and Development, Appalachian Center, West Virginia University, Morgantown, 1968); and H. A. Howard, "A Measurement of the External Diseconomies Associated with Bituminous Coal Surface Mining, Eastern Kentucky, 1962-67", *Natural Resources Journal* 11 (January 1971): pp. 76-101.

[19]See Brooks, "Strip Mine Reclamation", p. 27.

[20]Syncrude Canada Limited, "Environmental Impact Assessment", volume 4.

[21]Brooks, "Strip Mine Reclamation", p. 28.

[22]Personal communication with T. Laidlaw of the Environmental Conservation Authority. These figures should only be considered as very crude estimates.

[23]In an address to the Petroleum Society of C.I.M., the Honourable W. J. Yurko, then Minister of the Environment, outlined the government's basic policy with respect to reclamation. Each site was to be left in a state of greater biological productivity than existed prior to commencement of operations, and to bring about this desired end, a levy of approximately three cents per barrel produced was to be charged each operator. "Will Environmental Requirements Limit Energy Supplies", address to the 25th Annual Technical Meeting of the Petroleum Society of C.I.M., Calgary, 8 May 1974.

[24]After some level of environmental damage, all other uses of the environment may be lost due to the excessive use of the waste receptor capabilities of the environment. This would imply that the total damages function would level off.

[25]We have implicitly assumed that the curves do not shift through time. This may not be a valid assumption. We will return to this question in the next section.

[26]After some level of activity, the services, apart from the waste receptor capabilities, that the environment has to offer may be totally destroyed, which implies that the transformation function may level off.

[27]This assumes that the price of oil remains constant. If it did not, as the operators moved into less productive leases, the unit costs of extraction would increase and the operator may attempt to raise his price accordingly.

[28]See the work of Krutilla and Fisher, *Natural Environments*, for attempts at such estimates.

[29]To be fair, the provincial and federal authorities with their joint Alberta Oil Sands Environmental Research Program have taken steps to alleviate these problems.

[30]See R. L. Spore and E. A. Nephew, "Opportunity Costs of Land Use: The Case of Coal Surface Mining", in *Energy: Demand, Conservation, and Institutional Problems*, edited by M. S. Macrakis (Cambridge: The MIT Press, 1974), pp. 209-223; and A. C. Fisher, J. V. Krutilla and C. J. Cicchetti, "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis", *American Economic Review* 62 (June 1972): pp. 605-619.

[31]Fisher, Krutilla and Cicchetti, *ibid.*

[32]*Ibid.*, p. 610. The authors feel that this increase is due to such factors as increases in population and per capita income, and rising education levels.

[33]Spore and Nephew, "Opportunity Costs", p. 210.

CHAPTER IV

MANAGEMENT OF THE ENVIRONMENT: A REGIONAL APPROACH

If all inputs into the tar sands operation were fully converted into marketable outputs, or if property rights were so arranged such that all relevant environmental attributes were in private ownership and these rights were exchanged in competitive markets, or if the assimilative capacity of the natural environment was unlimited, we would have no uncompensated external diseconomies. The "market" would provide the optimum level of reclamation and environmental damage, and the problems of the last chapter would have been handled privately with no need for governmental intervention. The environmental property rights, however, are not so arranged, and the production of residuals is an inherent part of tar sands development. Still, if the assimilative capacity were unlimited, the residuals could flow into the environment without limit and without cost. But such is not the case, and in fact, the assimilative capacity of the environment should be looked upon as " . . . an important natural resource of rapidly increasing value."[1] Once this capacity is reached, further residuals discharge into

the environment will impair the other services that the environment has to offer.[2]

The problem is compounded by the fact that the property rights pertaining to this resource are not clearly defined: the preference orderings of present, or potential, consumers of the environmental services and the production functions of the oil sands operators are not independent. External diseconomies may result, with the external costs to society being composed of either monetary costs for the treatment of residuals, or biological and physical damage to the environment.

The traditional approach to residuals management problems has been to consider the different forms that the residuals might take, or the different mediums to which they may be discharged, as separate problems. Most of the residuals, however, can be readily transformed from one form into another, or discharged into another receiving medium. And though the characteristics of the residuals may be altered somewhat, the residuals still exist and must be dealt with. Moreover, given that the residuals do not pass through the market place, and consequently are not assigned their appropriate dollar values, one is forced to deal with the actual physical quantities of these "outputs", rather than with their values.

Thus, while the traditional partial equilibrium view of the matter may be more tractable, it may lead to serious oversimplifications. To combat these apparent

weaknesses, a more comprehensive approach, as suggested by a regional residuals management model, may prove desirable for such as the tar sands.[3]

A Residuals Management Model[4]

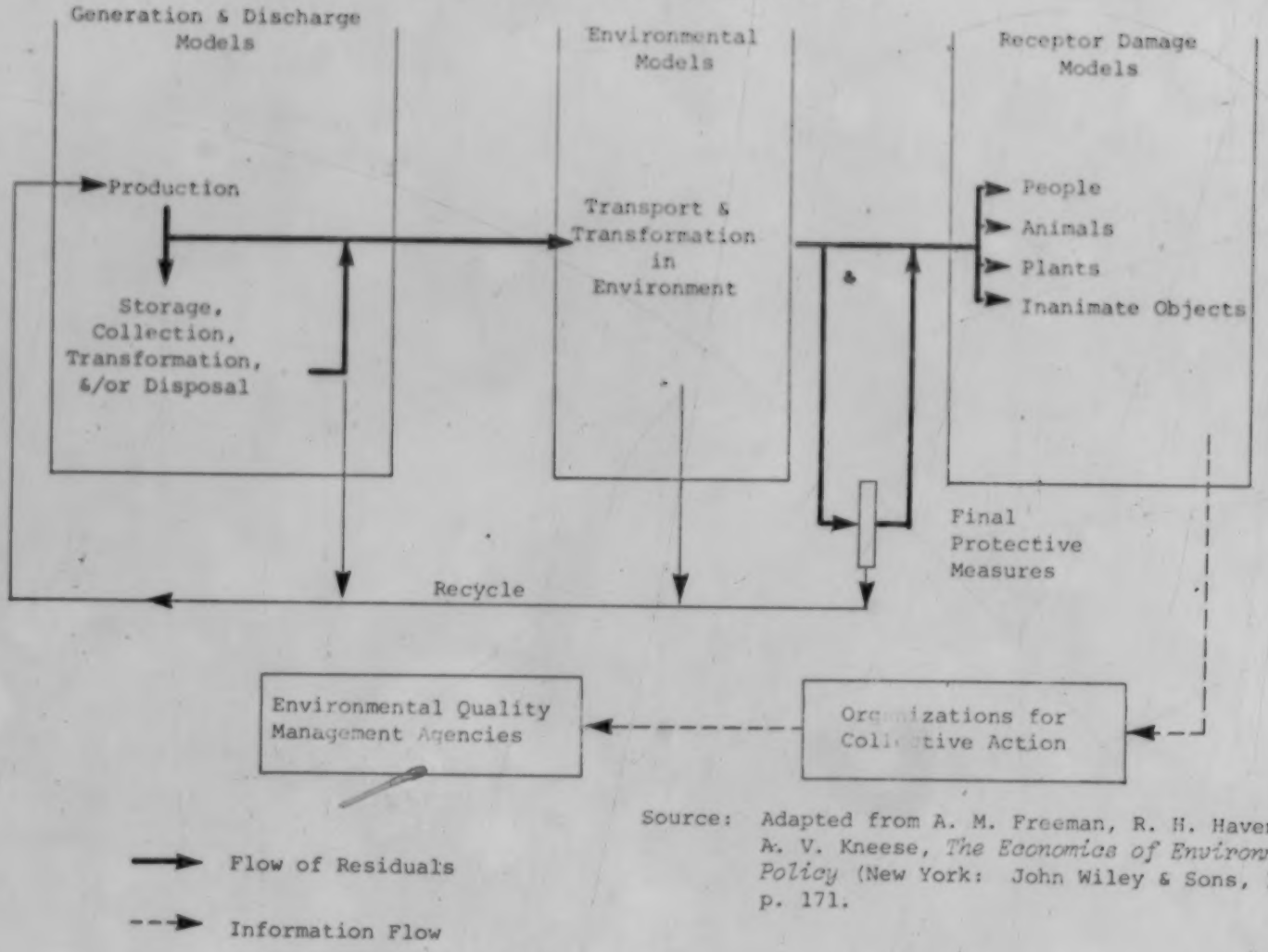
The residuals management model presented here consists of three interdependent components or sub-models, and is depicted schematically in Figure IV-1. Within this framework, the flow of residuals can be traced from the source, through the environment, to the receptors.

The source consists of the production activities of the individual tar sands operators, for it is from here that the residuals originate.[5] The actual volume of the residuals discharged into the environment will depend upon the number and scale of plants operating in the tar sands area, and some preliminary estimates on residuals discharge and tailings ponds size were given in the last chapter.

Once the residuals have left the productive sector, they enter the natural environment. In this sector or component, we are concerned with the natural diffusion characteristics or assimilative capabilities of the environment. These properties, which ideally would be quantified in the form of transformation functions, consist of the accumulation, dilution, transformation and transportation of the discharged residuals over time and space.[6]

FIGURE IV-1

A RESIDUALS MANAGEMENT MODEL



Source: Adapted from A. M. Freeman, R. H. Haveman and A. V. Kneese, *The Economics of Environmental Policy* (New York: John Wiley & Sons, 1973), p. 171.

For any given residual, we need to be able to relate the quantity discharged from a particular production activity, be it from a single source or several, to its contribution to the total ambient concentration at a given receptor location.

This leads us into the third component which consists of the damage functions reflecting the impact of the ambient concentrations on receptors. The extent of these damages will be a function of the amounts and types of residuals discharged, and the use of final protective measures to screen out the effects of rising concentrations.

What follows will be an attempt to consider these components in greater detail with the aim in mind of considering a possible "solution" to the tar sands residuals management problem. The model attempts to trace the interaction of the productive activities and the environment, and account for the origin, flow, and final resting place of all residuals. In turn, the receptors, either directly or indirectly, react to these residuals, and hence, we have a corresponding flow of information to the organizations and agencies responsible for "collective action" (see the lower portion of Figure IV-1). Here is where the policy decisions--the standards and enforcement procedures, the pricing and taxing alternatives, and the public investment decisions--will be determined and implemented for the protection of the natural environment.

The Source

The physical operation of each tar sands strip-mining project consists of nine relatively distinct activities:

(1) exploration,
(2) site preparation,
(3) overburden removal,
(4) strip-mining,
(5) extraction,
(6) tailings placement,
(7) upgrading,
(8) tankage and pipeline, and
(9) utilities.

While these activities are readily discernible, it is not to be assumed that each can be considered in total isolation. On the contrary, the rationale underlying a regional residuals management model implies the opposite. A change of technique in one area of the operation could conceivably have a significant effect on another. And it is on these alternative and competing techniques, with their consequent differences in residuals generation, that we wish to focus our attention.

For example, consider the existing technology that is employed by the present, and proposed, operators to separate the oil from the sand: the Clark hot water extraction process. This process requires enormous amounts of water. This water largely determines the size of the

tailings ponds, and associated with the ponds are serious environmental effects.[7] If a new technology were to be developed, one that substantially reduced the fresh water requirements, the ecological implications of tar sands development could be altered significantly.

The development of a new technology will undoubtedly take a great deal of time and effort. However, even a change in a fundamental engineering decision, using existing technology, can have a significant effect on total residuals generation. By way of an example, let us consider the effects of selective mining. Syncrude maintains that the first major problem facing the designer of a tar sands installation is the variability of the formation.[8] The bitumen content, the fines (silts and clays mixed in with the tar sands) distribution, and the chemical composition of the tar sands will greatly influence the design of the front end of the plant. The fines have a detrimental effect on processing, and vary inversely with the bitumen content of the mined material. Selection of the optimal cut-off point between overburden and commercial tar sands involves a balance between mining and processing costs. As the operator becomes more selective, the average bitumen content of the feed increases and the fines content decreases (see Table IV-1). Based on Syncrude's estimates, the amount of material handled is minimized at a cut-off rate of 6 weight per cent (see Table IV-2). As the grade improves, the tar sands feed rate decreases,

and consequently reduces the required size of the extraction facilities. Furthermore, up to the 6 weight per cent cut-off point, the overall conservation of bitumen (defined as the overall recovery of bitumen in mining-extraction-froth treatment operations) decreases by only small increments, whereas it decreases at a far greater rate for cut-off points above this. Selective mining will also influence heat requirements, which are numbered in the billions of BTU's per hour (see Figure IV-2), the water requirements, which directly determine the size of the tailings ponds (see Table IV-3), the size of tankage between extraction and upgrading facilities, and, of course, the costs of the operation (see Figure IV-3).

TABLE IV-1

EFFECTS OF SELECTIVE MINING ON FEED QUALITY

Bitumen Content of Reject, %	Average Bitumen Content of Feed, %	Average Fines Content of Feed, %
0	8.8	24
2	10.3	18
4	11.2	14
6	11.8	11
8	12.5	8
10	13.5	5

Source: Syncrude Canada Ltd., "Environmental Impact Assessment, Vol. I.

TABLE IV-2

EFFECTS OF SELECTIVE MINING ON MINING RATES AND BITUMEN CONSERVATION*

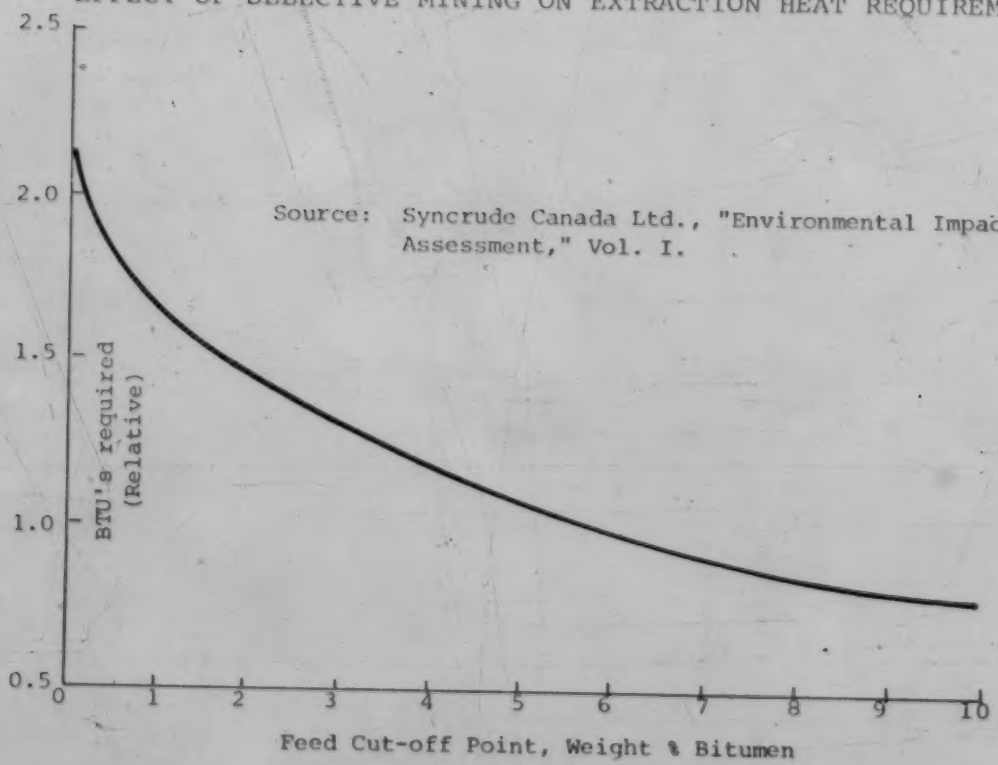
Bitumen Content of Reject, %	Total Mined Overburden, Tar Sand and Reject, M tons/CD	Tar Sand Feed, M tons/CD	Conservation of Bitumen, %
0	239	207	87.9
2	229	176	87.8
4	221	158	87.0
6	213	147	85.0
8	215	137	80.2
10	221	126	73.6

*Conservation is defined as the overall recovery of bitumen in mining-extraction-froth treatment operations; the units, M tons/CD = thousand tons per calendar day.

Source: Syncrude Canada Ltd., "Environmental Impact Assessment," Vol. I.

FIGURE IV-2

EFFECT OF SELECTIVE MINING ON EXTRACTION HEAT REQUIREMENTS



Source: Syncrude Canada Ltd., "Environmental Impact Assessment," Vol. I.

TABLE IV-3

TAILINGS POND REQUIREMENTS VERSUS CUT-OFF POINT OF FEED

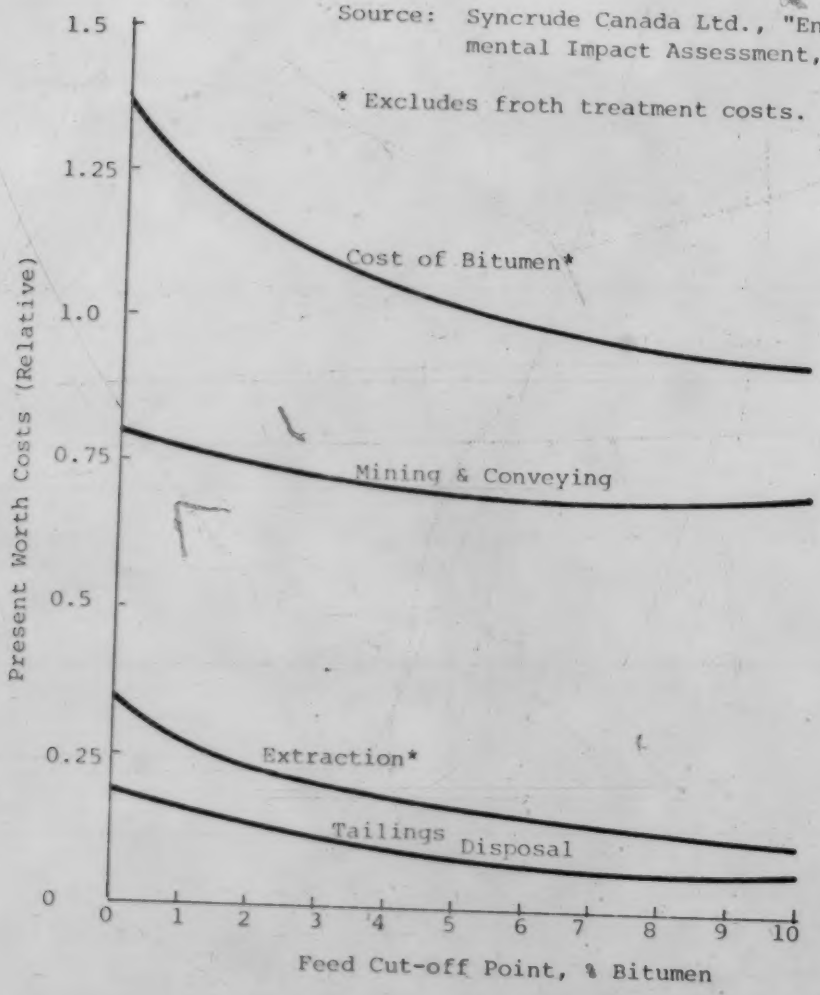
Cut-off Point of Feed, % Bitumen	Relative Settling Area	Relative Retention Volume	Relative Dam Size
0	1.43	2.21	2.78
2	1.15	1.53	1.80
4	1.07	1.08	1.27
6	1.00	1.00	1.00
8	.91	.72	.63
10	.84	.59	.50

Source: Syncrude Canada Ltd., "Environmental Impact Assessment," Vol. I.

Essentially what we require is some kind of programming model that would relate the inputs with product and nonproduct outputs under varying assumptions (e.g. cut-off points and activity levels). These nonproduct outputs, or residuals, can be defined as the difference between inputs and desired outputs (the synthetic crude oil in our case). The residuals are what remains to be handled, modified, and disposed of. Incorporated within the model would be the options for reducing, modifying, handling, and transporting the residuals, in whatever form, up to the point of discharge into the natural environment. Specifically, the model must permit choice among alternative productive processes, input mix, recycling and by-product possibilities, and in-plant adjustments, including residuals modification (i.e. treatment) processes and discharge location.

FIGURE IV-3

EFFECT OF SELECTIVE MINING ON PRESENT WORTH COSTS



The actual application of the programming model presupposes the availability of a considerable amount of detailed information. Given the scale of development of the tar sands, this data collection and coordination will be a formidable problem. The operators themselves, however, can provide a great deal of this information even

before they commence operations. In their attempts to design a facility that will maximize profits, the individual operators must consider alternative techniques. And with these considerations go flowsheets and materials balance calculations.[9]

In the absence of any regulation, management, or ownership of the environment, the residuals generated and entering the environment would vary directly with the rate of production of the synthetic crude oil, and we would expect this to be a function of the profit maximizing possibilities as perceived by the individual operators. The chosen level of production would undoubtedly be non-optimal from society's point of view, however, for no account would have been made of external costs imposed on others, which would arise as the operator attempted to dispose of his residuals in the (privately) cheapest fashion available to him. The incentive structure pertaining to the use of these resources must be altered. Consideration must be given to policies that force the operators to either reduce the flow of residuals (via recycling techniques, changes in input mix, and so on), or to "treat" the residuals before discharge. Treatment will not reduce the mass of residuals, but it will, hopefully, reduce their harmful effects, either by altering their form or their discharge location.

The problem comes down to determining the "optimal" level of product and nonproduct outputs. With the aid of the materials balance calculations from the opera-

tors, we can get information on both of these outputs. From this information we must construct the programming models, or generation and discharge models as they are often referred to in the environmental literature. And given these models, and some initial level or activity, we can determine the corresponding set of residuals. These residuals become the inputs into the next set of models to which we now turn.

The Environmental Models

Environmental models, including air and water dispersion, chemical reaction, and models of ecosystems, are necessary if we are to understand and evaluate the impact of the energy and material residuals discharged from the various production activities. Given the rates or set of rates of discharge as determined in the generation and discharge models, and given the environmental parameters[10], these environmental models will allow us to specify the ambient concentrations of residuals at the various receptor locations.

But again, the prerequisite for model building, and application, is an enormous amount of information. The Alberta Conservation and Utilization Committee Oil Sands Climatological and Meteorological Research Task Force concluded that the available meteorological and climatological data for the oil sands and surrounding region was completely inadequate.[11] The only continuous long-term

hourly records were from the Fort McMurray Airport. This location, however, is far from being representative of the conditions that prevail in the north-south section of the Athabasca Valley where the extraction plants will be located.[12] The Committee's Hydrological Research Task Force held similar reservations, claiming that, " . . . at present we cannot predict even the simpler natural hydrological characteristics of the river,"[13] let alone simulate surface runoff and groundwater flow systems in the mining areas.

To alleviate the data insufficiencies, the Climatological and Meteorological Research Task Force called for a large research effort, and recommended that this be conducted on the basis of several scales of atmospheric phenomena.

Scale	Representative Distances
Micro-scale	less than 5 miles
Meso-scale	5 - 100 miles
Synoptic scale	100 - 2000 miles

Again, we must realize that many of the residuals can be readily transformed from one form into another, or discharged into another receiving medium, and therefore,

> A coordinated, integrated network is desirable, involving hydrologic stations, meteorologic stations, and groundwater observation sites.[14]

Ideally, we want to relate marginal damages to types and sources of residuals. Consequently, for a given

residual from a given productive activity, we need to relate the quantity discharged with its corresponding contribution to the total ambient concentration at a given receptor location. If we assume a deterministic and steady state world, i.e. the attributes of our environmental models are known with certainty and do not vary with time, with noninteracting residuals, the relationship, or transfer function, degenerates to a constant.[15] For a specified receptor location, this constant, or transfer coefficient, measures the change in ambient concentrations of a given residual for a unit change in the rate of discharge of that residual from a single source. Expressed mathematically:

$$R^k = a^k x^k$$

where R^k = ambient concentration of the k^{th} residual
a^k = transfer coefficient for the k^{th} residual
x^k = rate of discharge of the k^{th} residual.

The transfer coefficient would be evaluated by using the appropriate environmental dispersion model. With the tar sands, each type of residual would originate from a number of sources, and the ambient concentrations of this residual, for a particular receptor location, would be determined by summing over all sources:

$$R^k = a_1^k x_1^k + a_2^k x_2^k + \ldots + a_n^k x_n^k$$

where the subscript denotes the source.

Given the possibility of multiple sources, each of the transfer coefficients must be evaluated separately based on the respective distance between receptor and source, values for the environmental parameters, and so on.

To generalize over all receptor locations:

$$R^k = A\ X^k$$

where R is a vector of elements, R_i, i = 1, . . . , m; A is a matrix of transfer coefficients containing the elements a_{ij}, i = 1, . . . , m, j = 1, . . . , n, relating the ambient concentration at receptor location i to a unit discharge of a residual from source j; and X is a vector of residual discharge levels with elements x_j, j = 1, . . . , n.

In the tar sands case, however, it is not easy to justify the assumptions of deterministic, steady state models with noninteracting residuals. For example, the summer atmosphere is relatively unstable. This instability is conducive to vertical mixing and thereby facilitates the dispersion of airborne residuals. Winter conditions, on the other hand, are generally stable, with frequent and intense inversions. These climatic conditions severely hamper the atmosphere's dispersion capacities. As Inteq notes,

> The Area [the Alberta tar sands] is susceptible to peculiar conditions of terrain and climate. Under adverse meteorological conditions ground level contaminant concentrations could be two or more times those values predicted under neutral atmospheric conditions.[16]

On the hydrological side, the dispersion capacity is also subject to wide margins. Flow measurements for the Athabasca River over the past fifteen years have ranged from a maximum daily discharge of 166,000 cubic feet per second, to a minimum of 3,730 cubic feet per second.[17] The flow, and the natural silt content, fluctuate seasonally, depending on conditions outside the tar sands area.

To alleviate the problem of sizeable variations in the values of the environmental parameters, we need more than one set of environmental models. That is, we need several sets, each based on varying assumptions as to stability conditions, wind speed and direction, stream flow, temperature, and so on.

Apart from the variability of the environmental parameters, the assumption of noninteracting residuals poses a problem as well. For example, the oil sands plants will emit enormous amounts of water vapour. The meteorological conditions are often ideal for the formation of ice fogs. The ice fog tends to attract water soluble airborne residuals, such as sulphur dioxide and, in the extreme, opens the possibility of "killer fogs".[18]

Given these qualifications, one must treat any results of the environmental models with a fair degree of

caution. The results will be, at best, an approximation of ambient concentrations at the various receptor locations. In time, perhaps we will have developed elaborate environmental models that will be able to trace a residual from the source to the receptor and explicitly account for variations in environmental parameters and residual interaction. In the interim, we will have to make do with the more simplified versions of the environmental models.

Receptor Damage Models

Given the ambient concentrations of the residuals at the various receptor locations, the next step consists of determining the corresponding set of damage functions, relating the

> . . . time and spatial patterns of ambient residuals concentrations to the resulting impacts on receptors--man, animals, plants and structures--in physical, biological, and economic terms.[19]

Several factors are of concern here, including such things as the amounts and types of residuals discharged, the specific transformation in the natural environment, the type and location of receptors, their use of final protective measures, and the values people attach to the physical, chemical, and biological effects caused by the residuals.[20] And again, we find ourselves operating in a world characterized by insufficient information.

For the moment, let us assume that we have somehow generated the necessary information so that we can

consider the nature of the damage functions associated with a particular receptor location. For location i, we will have a vector of ambient residuals concentrations, $R_i^{(k)}$, as determined by the generation and environmental models. For this same location we will have a set of human activities, or natural activities that are of interest to man. Some of these activities will be affected, to a varying degree, by one or more of the residuals.

For example, if location i were a section of the Peace-Athabasca Delta, certain residuals could conceivably have an effect on the migratory bird population which frequents the area. The accidental release of oil, or other contaminants, into the Athabasca River could reach the Delta, and could prove harmful to the birds directly, or indirectly through adverse effects on the supporting vegetation.[21] This latter possibility is increased several fold if, in addition to the water borne residuals, we consider the effects of sulphur dioxide on vegetation. Or, what of the effect of sulphur dioxide on location i, where location i is the town of Fort McMurray? Not only would the sulphur dioxide have an effect on the vegetation in and around the town, but it would affect the structures as well. Sulphur dioxide is corrosive and if we are to keep the buildings at some particular level of repair and appearance, increasing concentrations would entail higher costs of paint and labour. Similarly, particulate fallouts would increase the cost of cleaning. Of far greater importance, however, is

the potential effect of the emissions on the "life processes". The damages associated with these direct effects on the quality of life are among the most difficult to quantify. We would first have to establish the physical relationship between concentrations of a residual and increased mortality or morbidity, and then estimate the social cost of these health effects.

In general, what we want to determine is the effect, in dollar terms, of each of the residuals on the human activities within the location. Essentially, what we would be measuring is the increased costs of carrying on an activity at a desired level for increasing concentrations of each residual. Given these relationships, the next step would be to sum up, for each residual, the total damage attributable to that residual for the receptor location in question. This would give us a set of composite damage functions, one for each residual, for a particular location:

$$DM_i^{(k)} = f\left\{R^{(k)}\right\}$$

If such composite functions are available for each of the M locations in the tar sands and surrounding area, the total damages attributable to the k^{th} residual could be expressed as:

$$D_T^{(k)} = \sum_{i=1}^{M} DM_i^{(k)}$$

And the total regional damages, from all k residuals, would be given by:

$$D_T = \sum_{k=1}^{K} D_T^{(k)}$$

Up to this point we have not considered the use of final protective measures (e.g. water treatment facilities) that may substantially reduce the damage. Once these measures are explicitly accounted for, the damage function becomes the sum of the costs of the final protective measures used and the damages that result in spite of their use.

The Solution

As mentioned above, the problem is to determine the "optimal" level of product and nonproduct outputs. To accomplish this task we must specify an objective function. For our purposes, we shall use the maximization of net social benefits as the objective. In this case, our objective function becomes the sum of the gross benefits to society from the production of the synthetic crude oil, B; the opportunity costs of the production inputs, C_p; the residuals treatment costs, C_T; and the subsequent damages caused by the ambient concentrations of residuals, D. In algebraic terms:

$$F = B\ (q_i,\ i=1,\ \ldots,\ k_1) - C_p\ (q_i,\ i=1,\ \ldots,\ k_1) - C_T\ (w_i,\ i=1,\ \ldots,\ k_2) - D\ (y_i,\ i=1,\ \ldots,\ k_3)$$

where F = value of the objective function;

q_i = activity levels of k_1 productive processes;

w_i = activity levels of k_2 residual treatment processes;

y_i = ambient concentrations of residuals resulting in damages to receptors at k_3 locations.

If this function is linear, or can be transformed into a piecewise linear form, and given that the constraint set is also linear[22], the problem may be solved by standard linear programming procedures.

To illustrate the linkage between the three models, we initially solve the generation and discharge models with no restrictions or prices on residuals discharge. The resulting set of discharges is then run through the environmental models to determine the ambient concentration of residuals at the various receptor locations. From here, using the damage functions, we can calculate the marginal damages attributable to each discharge, by changing the discharge a small amount. These marginal damages, which can serve as a proxy for effluent charges on the discharge activities, are then incorporated into the generation and discharge models. Solving once again for these models gives another set of discharges, which, in turn, is fed into the environmental models and damage

functions. This iteration process continues until the set of production, treatment, and discharge activities converges to an optimum (maximum net social benefits). Also, from this technique, will come the effluent charge set necessary to bring about the desired objective.

The actual construction and application of this regional residuals management model will require an enormous amount of time and effort, not to mention money; furthermore, one discipline alone cannot hope to solve the entire system. The environmental problems, however, are making their effects felt in the present. Despite the uncertainties involved, steps to combat these problems must be taken now--steps that will hopefully avoid irreversible environmental damages. To these steps we now turn.

Footnotes

[1]A. V. Kneese, R. U. Ayres, and R. C. D'Arge, *Economics and the Environment A Materials Balance Approach* (Baltimore: The Johns Hopkins Press, 1970), pp. 4-5.

[2]The discharge of residuals is not a sufficient condition for the existence of pollution. If the residuals, or some level of residuals, has no discernable effect on the environment (or its services), then pollution has not occurred. However, as Freeman, Haveman and Kneese point out, " . . . it may be the insensitivity of our instruments or our ignorance that prevents us from perceiving the more subtle, long-range and indirect damages that our actions are causing." *Environmental Policy*, p. 24.

[3]The model presented in the last chapter and the one presented here are completely compatible with one another; the one presented here is of a more encompassing nature--in fact, the model of Chapter III may be considered a sub-model of the present one.

[4]The model presented here follows the one suggested by C. S. Russell and W. O. Spofford, "A Quantitative Framework for Residuals Management Decisions", in *Environmental Quality Analysis: Theory and Method in the Social Sciences*, edited by A. V. Kneese and B. T. Bower (Baltimore: The John Hopkins Press, 1972), pp. 115-179. See also C. S. Russell, "Models for Investigation of Industrial Response to Residuals Management Actions", in *The Economics of the Environment*, edited by P. Bohm and A. V. Kneese (London: Macmillan, 1971), pp. 141-163; W. O. Spofford, "Total Environmental Quality Models", in *Models for Environmental Pollution Control*, edited by R. A. Deininger, (Ann Arbour: Ann Arbour Science Publishers, 1973), pp. 403-433; and Freeman, Haveman and Kneese, *Environmental Policy*, pp. 170-175.

[5]The increased human activity in the area will also lead to residuals generation, but these are of relatively little concern as compared to those generated by the production activities, and so we shall ignore them in the present analysis.

[6]Analogous to the more familiar physical diffusion models would be models of ecological systems. These models reflect the transmission over time and space of the impact on natural systems of a particular residual discharge. See Russell and Spofford, *ibid*, p.22.

[7]See Environment Conservation Authority, "Review of Interaction Between Migratory Birds and Athabasca Oil Sands Tailings Ponds", Alberta, 1975.

[8]See Syncrude Canada Ltd., "Environmental Impact Assessment", Vol. I (September 1973), pp. 35-40.

[9]See Syncrude Canada Ltd., *ibid*, for examples of these flow sheets and materials balance calculations.

[10]The environmental parameters relate to the hydrological, meteorological, physical, biological and chemical characteristics of the region.

[11]Alberta Conservation and Utilization Committee, "Alberta Oil Sands Climatological and Meteorological Research", Alberta, 1974, p. 8.

[12]*Ibid.*

[13]Alberta Conservation and Utilization Committee, "Alberta Oil Sands Hydrological Research", Alberta, 1974, p. 1.

[14]*Ibid*, p. 7.

[15]These assumptions would be very restrictive for such as the Alberta tar sands. We shall return to this problem in a moment.

[16]The Integ Report, p. 30.

[17]A. H. Laycock, "Water Problems in Alberta Oilsands Development", *Proceedings of a Symposium on Water Resource Problems Relating to Mining*, American Water Resources Association, Proceeding No. 18 (June 1974), p. 197.

[18]Even if the fogs are not produced, the sulphur dioxide and water vapour will still combine, and form a weak acid. Dr. P. Summers, chairman of the Alberta Oil Sands Environmental Research Program (OSERP), claims that similarly produced acids, originating from factories in Britain, Poland, and the Ruhr Valley, have "rained" in Norway. The results have been disastrous for the fish populations in many of Norway's southern lakes. The lakes and forests of Saskatchewan could likewise be affected by the acid rains originating from the tar sands area. See the *Edmonton Journal*, Wednesday, December 10, 1975.

[19]Spofford, "Total Environmental Quality Models", p. 406.

[20]See Kneese, Haveman, and Freeman, *Environmental Policy*, p. 173.

[21]See Environment Conservation Authority, "Review of Interaction".

[22]The constraint set may include limits on input availability; quality requirements and product specifications; limits on discharge of one or more residuals; and continuity conditions, i.e. mass and energy balance equations. See Russell, "Models for Investigation", pp. 145-146. If we cannot satisfy the conditions of linearity, some nonlinear programming technique must be adopted. The general conclusions will be the same, but the application of the model will be all the more difficult. See Russell and Spofford, "Quantitative Framework", pp. 130-135.

CHAPTER V

DEVELOPMENT OF THE ATHABASCA TAR SANDS: TOWARDS AN INTERIM ENVIRONMENTAL MANAGEMENT POLICY

> A single plant of the Syncrude type is an enormous challenge in itself . . . but ten or twenty such plants present a challenge which is presently almost beyond comprehension.[1]

The "challenge" the Honourable W. J. Yurko (then Minister of the Environment) contemplated has many facets, not the least of which are the environmental ramifications.

The Syncrude officials have voiced similar concerns, maintaining that the key question before government authorities centers around the dilemma of exploitation of a particular resource versus the potentially disastrous deterioration of the quality of the natural environment.[2] In their own defence, the Syncrude officials contend that very few resource development projects of this magnitude could unconditionally guarantee the preservation of the existing ecosystems.

Even if such a guarantee were technically feasible for such as the tar sands, it would most likely be rejected on economic grounds. For the operators to preserve the existing ecosystems while attempting to develop

their lease holdings would be both difficult and expensive. Such preservation, be it in the form of pollution control or reclamation or whatever, absorbes resources--scarce resources--resources that could be employed in alternative, and perhaps more beneficial uses. Both Chapters III and IV support this contention and attempt to demonstrate, albeit nonquantitatively, that there is an "optimal" level of environmental damage, and this optimum may be significantly different from zero. What must be determined is whether the gain from preventing the harm to the ecosystem is greater than the loss which would be suffered elsewhere as a result of restricting the activity which produces the harm, or which would result from investing further resources into reclamation efforts.

One must be cautioned that this is not an "either-or" situation; rather, it is one of degree. As industry attempts to recover greater portions of the ultimate reserves, the quality of the environment will face increasing pressures. To some degree this quality will be forfeited. Nor is the process static in nature. Changes in technology, in social institutions, and in economic institutions have a tremendous impact and give a dynamic edge to the whole tar sands development scheme. Policy, however, is made in the present, given existing technology and institutions, and uncertainty is a most prevalent and often perverse factor.

The purpose of this chapter is twofold. First,

the development strategies put forth by Kahn[3], Levy[4], Yurko[5] and The Conservation and Utilization Committee[6] will be briefly discussed and criticized. Secondly, another approach, one that is basically theoretical and aimed at the decision making process per se, will be developed. This latter approach is derived directly from a concept developed by Ciriacy-Wantrup.[7] This concept, known as "a safe minimum standard", was designed specifically as an objective of conservation policy. In the strict sense, it was meant to apply only to those flow resources characterized by a critical zone.[8] An attempt will be made here to generalize the theoretical underpinnings of this concept, and then to apply this generalized form, not only as an objective of conservation policy, but as an objective of development policy in general, for the whole tar sands area.

The Proposed Strategies

Kahn

As mentioned above, the development "challenge" has many facets. Some decision makers may have a tendency to aggrandize certain aspects of development to an excess, often to the detriment of other aspects--a classic example being the gradiose scheme of Herman Kahn. Kahn met with Prime Minister Trudeau, Energy Minister Macdonald, and other high level government authorities to propose what

he believed to be an answer to the "free" world's energy shortage. In essence, the proposal called for an international consortium of governments, consisting of the United States, Japan, and Western Europe, to invest some twenty to thirty billion dollars. By 1980, twenty plants, fed by massive strip-mining operations, were to produce some two million barrels of synthetic crude oil a day, all of which was to be exported to the three investors. To meet the gigantic labour requirements, 30,000 to 40,000 South Koreans would be imported. And to circumvent the need for huge tailings ponds, the liquid wastes would simply be dumped into the Athabasca River.

With such a plan, not only would the Athabasca River, and the whole of Northern Alberta for that matter, be irreparably damaged environmentally, but such rapid and large scale development would have far reaching implications on the rest of Canada. The massive population influx would severely strain the infrastructure of social services, housing, and the like. The enormous demand for various goods and services could unleash tremendous inflationary pressures. The total labour requirements, over and above the South Koreans, would call for huge numbers of skilled craftsmen, engineers and managers. In short, the disruptive consequences of such a scale and pace of development would be phenomenal. While one may readily dismiss Kahn's proposal as absurd, the realization that a federal cabinet minister, the Honourable J. P. Goyer, could also

adhere to a rapid development plan, a plan quite reminiscent of Kahn's, gives the whole situation a rather ominous dimension.

Levy

A more realistic attempt to formulate a development strategy was put forth by Walter J. Levy. But again, certain aspects of the problem were allowed to dominate, if not cloud, the issue. As with Kahn, the central theme was a call to secure an adequate and "safe" source of supply of crude oil for the "free" world. While twenty plants by 1980 were not explicitly called for, Levy did advocate rapid and large scale development. In fact, Levy claimed that it would be in the best interests of Alberta to get projects underway as rapidly as possible so as to take full advantage of the "energy crisis".[9]

Timing would seem to be a critical factor in the Levy analysis. At least through the early 1980's, the United States will face an increasing deficit between oil requirements and indigenous crude oil production. For 1972, total American imports amounted to approximately twenty-nine per cent of domestic product demand. But, based on a survey of various government agencies and industry, this dependence is projected to grow to a minimum of thirty-seven per cent, up to a maximum of sixty-six per cent between the years of 1980 to 1985.[10]

However, over the long run, tremendous uncer-

tainties render any quantitative analyses impossible, and any qualitative ones highly suspect. The Americans will undoubtably take steps to improve upon their position, for as Levy notes,

> The United States simply cannot afford an ever-increasing over-dependence for its oil supplies on a handful of foreign, largely unstable, countries. Otherwise, its security--and that of its allies--as well as the prosperity and freedom of action in foreign policy formulation will be in jeopardy. But the United States does have a realistic and economically manageable alternative--accelerated development of its large domestic resource potential for conventional and synthetic hydrocarbons and nuclear energy.[11]

Given the uncertain outcomes, time alone will dictate the success of these efforts; much rests on the success of frontier exploration. Consideration must also be given to those measures which would either improve efficiency in recovery or utilization or both, as well as to those measures which would conserve energy.

Another area of consideration, and of paramount importance to the present study, is the place of Canadian crude oil in the American future. Historically, even with Canadian oil receiving preferential treatment over other foreign sources, its ease of movement into the southern market bore an inverse relationship to the availability of American indigenous supply. In 1962, this prompted Alberta's Social Credit government to defend the conventional oil industry from further tar sands developments. With the belief that conventional and synthetic crude oil would be competitive, the government took it upon itself

> . . . to ensure that the position of conventional oil production in Alberta is not jeopardized by the loss of already limited markets to a new source of supply.[12]

The policy statement of 1968[13] took a more lenient approach and, of course, with the chain of events of recent years, the rationale underlying the policies of 1962 and 1968 is no longer credible. A similar fate would seem to be in store for American import policy with respect to Canadian oil;

> . . . with domestic production at or near capacity and total U.S. oil imports inevitably rising sharply, concern with the impact of Canadian oil on domestic and other foreign supplies has largely disappeared.[14]

Thus, Levy was forced to conclude that Canadian oil will continue to be a preferred source of supply, " . . . almost irrespective of price," with U.S. imports " . . . basically a function of the ability and willingness of Canada to deliver."[15]

When the Levy proposal was made in 1973, it appeared that tar sands developments were not essential to meet Canada's domestic requirements for some time to come.[16] Despite this, Levy argued that Canada would receive substantial benefits from rapid development of the tar sands. Again, timing is the crucial factor in Levy's analysis. The oil sands have established an early lead in the development of technology over the other North American sources of synthetic hydrocarbons. Some would argue that present circumstances are conducive to increasing this lead. In fact, Levy contends that rapid development may

only sustain, not increase, the present margin.[17] In this respect, early development could lead to the establishment of a "base-load" position for tar sands production, and insulate it from the potential impact of large-scale developments of other North American producing areas.

It is quite apparent from the GCOS and Syncrude experience that tremendous capital investments would be required to bring about this base-load position. J. Poyen, president of the Canadian Petroleum Association, makes some interesting comparisons in this respect.[18] Poyen estimates that capital investment in tar sands mining is in the order of $10,000 per barrel per day productivity, as compared to $8,000 in the Mackenzie delta, $5,000 in the North Sea, $300 in the Middle East, and $2,500 for Canadian conventional reserves.[19] Moreover, as Poyen points out, a conventional producer can go on production with one well and hypothecate the cash flow for a loan to drill another.[20] With an oil sands operation, however, all the capital investment must be in place before production can begin. Poyen also estimates operating costs at $3 to $3.50 per barrel for tar sands but only 50 cents a barrel for conventional reserves (in 1974 current dollar figures). Given these estimates, one can understand Levy's contention that

> . . . the economics of tar sands operation virtually requires that they supply a base load.[21]

Herein lies the crux of the Levy analysis: to capture

this base load position, development must proceed quickly; to delay could run the risk of the major oil companies bypassing the oil sands altogether.

This latter possibility is heightened by the uncertainties of the Middle East situation.[22] With the political unrest, and the threat of increased "participation" or possibly nationalization, the majors are being forced to consider more secure sources. With Alberta's conventional oil production peaking within the next few years, and if tar sands developments are held back, or pertinent policies shrouded in uncertainty so as to leave operators in doubt as to the nature and extent of government regulations in this area over their planning horizon, then there is always the possibility that the majors will turn their efforts to alternative sources, such as the Colorado shales or some promising frontier area. Hence, Levy would conclude that "time" will not wait for the oil sands.

While Levy goes to great lengths to develop his arguments for rapid tar sands development, one must question the scope of his analysis. With a title of "Emerging North American Oil Balances: Considerations Relevant to a Tar Sands Development Policy", one might expect some account of environmental concerns, effects on related sectors of the economy and its overall stability, foreign ownership considerations, and so on. But under the section entitled "Canadian Policy Issues", where

Levy continues to dwell upon the possibility of Canada's maintaining its export potential, the negative aspects of development are relegated to a single paragraph.[23]

Apart from the seemingly inadequate treatment of several prominent aspects of the development problem, Levy's primary justification for rapid development also deserves closer scrutiny. Levy claims that rapid development is necessary for Canada to maintain its export potential. And while rapid development may very well be a necessary condition for such an end, it is by no means a sufficient one. Over the long run, even if Canada actively pursues a policy of rapid tar sands development, there exists the possibility that any efforts to sustain its export potential may be for naught. This contingency does not rest upon any lack of recoverable reserves, nor upon any inherent technological or economic miscalculation. Rather, the implementation of enlightened energy and import policies on the part of the Americans may circumvent the need for Canadian oil exports. Consider a few of the possibilities: more intensive development of presently producing areas; increased exploration, and subsequent production, of frontier areas; accelerated development of synthetics from shale and coal; and extensive research into the relatively new sources of energy such as fission, fusion, geothermal or solar. Nor should one ignore the potential impact of conservation policies, and their subsequent effects on demand.

At present, one can only speculate on the nature and possible success of any policy. Numerous options are open, affecting either demand or supply, or possibly both. The "price mechanism" may not be perfect, but it may still work admirably. With a change in supply and/or demand conditions in one sector of the economy, relative prices may be affected. Standard economic theory then dictates that there will be a reallocation of resources. In the present context, as the world price of oil rises[24], American indigenous supply of oil (and other forms of energy) should increase and the quantity demanded should fall.

Uncertainty, however, remains the dominating factor, leaving the total magnitude of U.S. oil import requirements virtually indeterminant. Levy himself acknowledges this contention in principle, but displays a distinct tendency to downplay the potential impact of any contingency that may adversely affect tar sands development.

Thus, one must entertain the possibility that future Canadian oil exports to the U.S. may be substantially curtailed.[25] If such is the case, much of the inevitable environmental damage and economic and social disorder directly attributable to rapid development could be for nothing. If development proceeds at a more conservative pace, perhaps much of this potential damage may be avoided, yet with production ultimately reaching the same magnitude, and at a much lower social cost. Much of the demand for

oil sands production stems from external sources, sources which have relatively little incentive to take full account of the potentially enormous social costs that may arise out of imprudent development.

It is quite apparent that both scale and timing of development are key policy issues, and issues that cannot be considered in isolation. Policy makers cannot afford to ignore the direct relationship between scale of operations and environmental impact, nor should they under-estimate the more subtle relationship between rate of development and environmental impact. In this light, one might object to Levy's apparent bias with respect to policy emphasis. Instead of emphasizing that "Policy cannot push development at an unrealistic pace"[26] would it not be more in the interests of Canadians to reverse the policy emphasis to that of, say, "policy can prevent development from proceeding at an unrealistic pace"?

Yurko

The Conservative government of Alberta had a very favourable reaction to the Levy analysis. Even the minister responsible for the protection of the environment, the Honourable W. J. Yurko, fully endorsed Levy's basic hypothesis of rapid and large scale development.[27] To the environment minister the most "optimistic" rate of development saw Syncrude's and Shell's surface mining operations joining GCOS on stream by the end of the de-

cade. In the early 1980's, a new plant was to commence production every one-and-a-half to two years, accelerating to one every year through the latter half of the decade. Each of these would have a capacity in the order of 100,000 to 150,000 barrels per day of synthetic crude oil; some would employ *in situ* technologies. Through the 1990's the rate of one plant a year would continue, but these would be second generation plants, with productive capacities ranging from 200,000 to 300,000 barrels per day. By the year 2000, roughly twenty plants would be in operation with a combined annual production of some three million barrels per day. "Time and politics will tell the true story. . . ."[28]

With these "optimistic" projections coming from an environment minister, one might wonder if both "time" and "politics" are stacked against the optimal rate of tar sands development.[29] Of course, to adequately define this optimal rate of development is a task of near impossible dimensions. To fully comprehend the significance of this fact is a tremendous step in the right direction, for such a realization would, in essence, recognize that uncertainty is a dominating factor, and a factor that must be accounted for from the outset.

The Conservation and Utilization Committee

> It would be unreasonable to demand that the state make economic policy decisions on the grounds of efficiency alone, especially when "efficiency" is used in the sense of thrifty production of saleable goods. For the legislature is free of the limitations of market valuations and may make policies independently of prices and costs, heeding only its own--*or its servants'*--appraisals

> of the losses and gains from its decisions. Such losses and gains may well transcend the estimates of the market pricing process and reflect some *notion of social benefits and social costs.*[30] (emphasis added)

In 1972 the "servants" were called upon for such an appraisal. Under the coordination of the Conservation and Utilization Committee (the Committee), some nineteen provincial departments and agencies were to

> . . . conceptually explore the numerous ramifications of the bituminous tar sands development and suggest a comprehensive development strategy . . . .[31]

Their systematic approach was broken into five basic components, consisting of:

(a) a social component which included those factors relative to health, education, work, recreation and cultural activities and the objectives and strategies leading to a satisfactory quality of life;

(b) an economic component which included the distribution of benefits and costs, maintenance of stability in the distribution of goods and services, diversification of development and the focus of economic activity beneficial to Alberta;

(c) an environmental component which included the physical and ecological ramifications of the development on the natural and human environment, the objectives and strategies which could be developed to ameliorate or obviate their impact or alternatively shape the impact to future advantage;

(d) a technical component which included the review of existing technology but emphasized the secondary and tertiary technologies for further industrialization and the impact of these technologies on the other components and those objectives and strategies required to complement other objectives;

(e) an administrative component which included the regional administration, co-ordinative and political factors and the appropriate

objectives and strategies required to implement the overall strategy.[32]

Working under the premise that the demand for synthetic crude oil is from markets external to Canada, the Committee continually expounded the belief that it becomes virtually "axiomatic" that the primary objective facing Albertans is the regulation, guidance, and control of all aspects of tar sands development, including the secondary and tertiary developments induced by and stemming from such development, to meet the expanding socio-economic needs of Albertans, and Canadians in general. Once the Canadian policy parameters have been fulfilled then, and only then, should "foreign constraints" come into play.[33]

The second order objectives continued within this line of thought, being most pro-Albertan in their emphasis. Development of the oil sands can serve Alberta's interests only if Albertans participate, and participate on a significant scale.[34] Effective participation includes the opportunity to share in the ownership of the companies involved; to receive a fair and equitable return on the depletion of the non-renewable resource; and to have Albertans and Alberta products employed in all phases of development. To "maximize" this effective participation, the provincial government must time and stage development in such a manner to "mobilize" Canadian factors of production in the direction of tar sands development.[35] Improper timing or staging could result in bottlenecks, or

worse yet, imports of foreign capital, labour, or products to a greater extent than absolutely necessary. The Committee saw the "intimate involvement" of Albertans and Canadians in tar sands development as a means " . . . to develop Canadian technology, the Canadian economy and ultimately the Canadian society . . ."; involvement was to be viewed " . . . primarily as a development lever and secondarily as a source of income."[36]

The environmental objectives were as equally pro-Albertan in content. In fact, once extractive operations were complete, the Committee called for an eventual "enhancement and improvement" of the environment for subsequent land use more beneficial to society than existed before commencement of operations.[37] However, policy formulation in these areas will be most complicated. In effect, what the Committee is demanding is that all environmental costs stemming from strip-mining operations be reduced to zero. This may not be compatible with the models presented in Chapters III and IV of the present study, and the desirability of such a goal might be questioned on efficiency grounds. Moreover, tar sands operators, as profit maximizers, have little or no incentive to voluntarily account for these social costs--in fact, they have a real and definite incentive to "externalize" as many of these costs as possible.

The Committee also notes that the degree of "confidentiality" adhered to by the tar sands operators

causes problems.[38] In the case of the conventional oil industry, the nature of the resource deposit may justify the high degree of confidentiality so as to maintain some illusive competitive advantage. But the tar sands deposits are quite different.[39] The Committee, therefore, argued that the information generated by the coring operations, as distinct from the seismic operations of the conventional industry, should not be held as confidential by the individual operators. The information should be pooled, for such pooling would make for better planning of the entire region and aid greatly in achieving the environmental objectives.

As owner of the resource in question, the government should realize the amount of "leverage" it has in negotiating with industry. Once the government realizes the degree of control that it may exercise, the environmental strategies, or any other strategies for that matter, proposed by the Committee, or any other government agency, can be implemented with ease.[40]

The Committee is quite right in its contention that the tar sands present a unique opportunity. The resource is proven and the markets are certain given the current world energy situation. The opportunity to increase Canadian equity participation in nonrenewable resource development and reverse the historical trend of increasing foreign control exists. And despite the fact that the Committee split their analysis into five compo-

nents, it was implicit throughout that no component was to take precedence over all others, nor was it meant for any component to be considered in isolation. Rather, the Committee pressed for a comprehensive and coordinated development strategy whose primary objective was the maximization of net social benefits to Albertans. In this respect, the Committee explicitly acknowledged the massive uncertainties involved, and repeatedly called for intensive and aggressive research into all aspects of development. The emphasis was on quality, not speed, of development.

A Safe Minimum Standard of Development

In October of 1974, Yurko wrote to his federal counterpart, the Honourable Jeanne Sauvé,

> . . . in the light of Canada's critical energy balance, it did not and does not appear prudent to delay oil sands development until *all needed information* is available.[41] (emphasis added)

Hopefully this is just a poor choice of words, but nonetheless it does serve to emphasize the fact that uncertainty is a prevalent factor in the whole development scheme. Various options exist to increase our knowledge of future contingencies, with industry's Athabasca Tar Sands Environmental Study Group and government's Alberta Oil Sands Technology and Research Authority being two cases in point. But all of these options necessarily involve costs of one sort or another. This leads us into what Frank Knight refers to as,

> . . . the fundamental issue as to the essential evil of uncertainty, how great it is and hence how much we can afford to sacrifice in other ways in order to reduce it. In this sort of calculation as in all economic problems we are dealing with a question of proportioning alternatives subject to a principle of diminishing relative importance. It would doubtless be possible to use all the resources of society with more or less effect in reducing uncertainty, leaving none for any other use. It is a question of how far to go. The question is complicated by the fact that the use of resources in reducing uncertainty is an operation attended with the greatest uncertainty of all.[42]

In addition to these words of caution on the optimum level of uncertainty control, Knight raises the question of "distribution" of uncertainty. In this respect, Knight notes that while large scale industry, with its advantage in efficiency, has a

> . . . degree of concentration of control in the immediate sense of executive direction,[43]

it does not follow that there is a corresponding concentration of responsibility. The ultimate responsibility, Knight insists, centers around the ownership of the property "at risk".[44]

To put these ideas into the context of a tar sands development policy, the major oil companies, with their "efficiency" advantage, provide the executive direction" but it is the provincial government, as owner of the resource, and as the representative of the people most affected by the development, which is ultimately responsible for development and its consequences. It is virtually axiomatic for comprehensive social planning that all

costs and benefits of a proposed development plan, to the extent that they can economically be determined, and regardless of who should benefit or be harmed, must be considered. On efficiency criteria alone, development should not proceed unless the net social benefit is greater than zero. However, given the nature and magnitude of the uncertainties involved with any tar sands development, determination of the net social benefits is near impossible--indeed, whether the net benefit will be positive or negative is uncertain as well. If development of the tar sands is to continue, then the policy makers, having "ultimate responsibility", would be best advised to proceed so as to ensure that the "safe minimum standard" is not encroached upon.[45]

The Concept and Its Application

Given the magnitude and complexity of any tar sands development, a flexible policy strategy must be devised--one that will permit the authorities to move in a series of short steps,

> . . . pausing before each to estimate the magnitude of extra social losses which may be afflicted, and getting assurances that they are more than offset by the expected extra social gains.[46]

Such a strategy provides the basis for Ciriacy-Wantrup's "safe minimum standard" of conservation. As this standard was designed specifically to take account of uncertainty directly, one can argue that it lends itself well to the

present task as an objective of development policy in general.

It is quite evident that as development of the tar sands proceeds, the policy makers will be increasingly confronted with choices between alternatives which include possible losses of various probabilities and magnitudes. In this respect, Ciriacy-Wantrup would argue that often

> . . . the possibility of larger but less probable losses can be avoided only by accepting the possibility of smaller but more probable ones.[47]

In particular, one must attempt to avoid what he refers to as "immoderate" losses--those contingencies which could threaten the continuity of a utilization plan or of a social group.[48] One such contingency of tremendous importance to tar sands policy is the threat of economic irreversibility of those flow resources characterized by "critical zones": the soil, the water, the plants and animals.

With the plants and animals, the critical zone would come into play with the destruction of the breeding stock, or its natural habitat; the interaction between the migratory birds and the tailings ponds is an obvious example.[49] The surface and ground water systems may be irreparably damaged if the mining operations should uncover saline aquifers. The same operations will remove the protective plant cover, opening the possibility of soil depletion from erosion, gullying, and changes in chemical composition.

Strip-mining operations will be competitive in supply with the present, or potential, recreational resources of the area. However, even if the decision makers found the recreational benefits of the area to be greater than the private benefits derived from extraction of the bitumen, the latter use may not be foregone. If a safe minimum standard was in force, the tar sands could be mined, provided the land was reclaimed to such an extent that the recreational resources could again be enjoyed.

> But, there is a legitimate question whether undisturbed natural environments should be allocated to extractive industrial activities on the supposition that they can be eventually restored. Even the most painstaking application of modern scientific-technological resources would provide replicas of the original that would satisfy the recreational interests of only the less discriminating clientele. The matter turns on the importance of authenticity as an attribute of the recreational experience, quite apart from the matter of preserving relevant research materials for advancing knowledge in the life and earth sciences.[50]

Because of the degree of uncertainty and the complexity of the tar sands situation, it is impossible to determine a social optimum rigorous in timing and scale of development. But it is possible, and indeed necessary, to set standards to ensure the economic possibility of halting and reversing a decrease in flow and future use of any resource that is so jeopardized. The safe minimum standard concept would seem to be the logical approach as it is designed to avoid "immoderate" losses. The approach is both flexible, permitting ready adaptation to local conditions,

and straight forward, being easily understood by the resource users and easily administered by the government agencies in charge of its execution.

Against these advantages, one must consider the time and effort that are required to devise the standard for each resource in question. Moreover, the optimal standard must be both technologically effective and economically efficient; even if the standard ensures that the critical zone is not encroached upon, it must also ensure that the same result could not be achieved by another standard at a lower cost.

The degree of difficulty in devising and implementing the safe minimum standard should not be blown out of proportion. It is not necessary, and often not possible, to define the standard in terms of a single flow rate which is to be maintained indefinitely; rather, it is far more practical to proceed in a series of short stages, each stage specifically designed to deal with the problem at hand, yet flexible enough to adopt to new circumstances. As new data comes in, the existing standard must be reassessed, and modified if necessary.[51] If the proper steps are initiated at each stage, the costs of maintaining the safe minimum standard must necessarily be small in relative terms. Indeed, if the costs were not small relative to the "immoderate" losses which are being guarded against, the philosophy underlying the concept would be faulty.

In some situations, maintenance of a safe mini-

mum standard may necessitate that all use be forgone, or at least postponed until more information becomes available to determine whether or not the use will in fact force the flow into the critical zone. In other instances, a change in the method of utilization, not an actual change in total use, may suffice.[52] Along with these costs are the resources used, or the costs incurred, by the decision making authorities to devise and implement the standards. Furthermore, given improvements in technology, there is always the possibility that the contingency being guarded against -- economic irreversibility--may not occur.

> These losses are similar to the costs of flexibility in private economics. The similarity is more than formal: as implied above, a safe minimum standard of conservation is essentially an *increase of flexibility* in the continuing development of society.[53] (emphasis added)

Seen in this light, the underlying rationale or philosophy of the concept of a safe minimum standard transcends the confines of those flow resources characterized by a critical zone, and can serve as an objective of development policy in general. The Conservation and Utilization Committee would seem to support this contention with respect to the options available to Albertans:

> On the one hand we can continue the policies of the conventional crude oil developments creating tremendous and unregulated growth and developments resulting in short term benefits accruing to the Province as well as the long term costs arising from exported energy, technology, job opportunities and environmental damages, in addition to the depletion of non-renewable resources.

> Conversely we can regulate the orderly growth and development of the bituminous tar sands for the ultimate benefit of Alberta and Canada in order that Canadian technology will be expanded, Albertans will find beneficial and satisfying employment within its diversified economy, and our environment will be protected and enhanced for future use.[54]

Thus, the possibility of "immoderate" losses envisaged by the Committee consisted of more than just those contingencies involving flow resources characterized by a critical zone. The potential losses are both tremendous, and perhaps irreversible. And while the short term losses of Alberta "controlled" development may have a greater probability of occurrence, they would appear to be quite small in comparison to those of rapid and foreign controlled development.

Adoption of a safe minimum standard as an objective of development policy need not interfere with the majority of the actions of the tar sands operators. In fact, industry should welcome this step by step approach over a more restrictive development strategy. The present approach allows industry to keep its "executive direction" for the most part, but protects both industry, and society in general, from the threat of economic irreversibility. However, one should not think that once a safe minimum standard has been assured that the problem is over. The concept is meant to serve as an economic "base level"--a plateau from which further steps may be taken toward the social optimum.

Concluding Comments and Observations

In the final analysis, what is needed is a massive, highly co-ordinated, multidisciplinary research effort on all aspects of tar sands development. Only after we have much detailed information on the environmental parameters, the biological and physical resources, industry's plans and processes, and the interaction of the three, will the models of Chapters III and IV become operational. Once we have reached this level of sophistication in environmental management, then and only then, can we hope to approach the "optimum state of conservation."[55] At present, however, the policy makers find themselves operating in a world characterized by limited information and uncertainty. Under such conditions, it is not possible to ascertain the optimum state of conservation. Flexible policy strategies must be devised--strategies that are progressive, moving us closer to the optimum, yet affording us the security that no "critical zone" will be encroached upon.

The contingency being guarded against--economic irreversibility--is not static in nature, for it depends upon the "presently foreseeable conditions" in technology, wants, and social institutions. As new information becomes available on any or all of these conditions, the standards must be reassessed and modified if necessary. In this respect, organizations such as the joint federal-provincial Alberta Oil Sands Environmental Research Program may figure

prominently in tar sands development. Under this program, three coordinators (one responsible for biological studies, one for physical resources, and one for human aspects of development) will organize the necessary research efforts into such environmental aspects as air and water quality, revegetation and reclamation, wildlife, and human environment studies. It is expected that much of the research effort will be carried out within the existing federal and provincial government agencies; universities and private consulting firms will also be approached. Other organizations, such as the provincial government's Alberta Oil Sands Technology and Research Authority and industry's Athabasca Tar Sands Environmental Study Group, can also provide much needed information.

To avoid duplication of effort, the coordination of these various organizations and agencies is necessary. Research priorities must be established and assigned to the proper agency for investigation. The immediate objective of each such investigation would be the generation of sufficient information to construct the safe minimum standard associated with the problem in question. For as noted by Ciriacy-Wantrup, the practical objective of conservation decisions is not the determination of the optimum distribution of use rates over time, but rather,

> . . . a step-by-step directional (conservation or depletion) change of the existing or some hypothetical distribution toward the optimum.[56]

The costs of maintaining a safe minimum standard are small relative to the costs of the contingencies being guarded against. In Chapter III, for example, the estimated cost of restoring an acre of land ranged from $200 to $2,000,[57] or from 0.12 cents to 1.2 cents per barrel. The latter per barrel figure amounts to only 0.15 per cent of the current Canadian price of a barrel of oil, and this price is expected to rise substantially within the next two months.

The problem, however, is that the 1.2 cents per barrel is to maintain the standard with respect to reclamation only. Clearly, we have several "critical zones" within the tar sands area that must be protected.[58] Standards must be devised and implemented for each if we are to avoid all the "immoderate" losses of development. "It will be a job of enormous, if not impossible complexity, one we would normally leave to God."[59]

Footnotes

[1]W. J. Yurko, "Environmental Problems in the Development of the Fort McMurray Tar Sands," address to the Instrument Society of America (Calgary, 23 January 1973), p. 2.

[2]Syncrude Canada Limited, "Environmental Impact Assessment," Vol. 1, (September 1973), pp. 3-10.

[3]For a brief discussion of the Kahn proposal, see Larry Pratt, *The Tar Sands: Syncrude and the Politics of Oil* (Edmonton: Hurtig Publishers, 1976), pp. 74-77; and Wade Rowland, *Fuelling Canada's Future* (Toronto: Macmillan, 1974), pp. 62-84.

[4]W. J. Levy, "Emerging North American Oil Balances: Considerations Relevant to a Tar Sands Development Policy," (New York, February 1973).

[5]W. J. Yurko, "Development of the Alberta Oil Sands," address to the Engineering Institute of Canada (Edmonton, 17 April 1974).

[6]The Conservation and Utilization Committee, "Fort McMurray Athabasca Tar Sands Development Strategy," (Edmonton, August 1972).

[7]S. V. Ciriacy-Wantrup, *Resource Conservation: Economics and Policies*, 3rd ed. (University of California: Division of Agricultural Science, Agricultural Experiment Station, 1968).

[8]With "flow" resources, different quantities become available for use in different time intervals--the successively available units constituting the flow. A "critical zone" can be defined as a ". . . more or less clearly defined range of rates below which a decrease in flow cannot be reversed economically under presently foreseeable conditions." *Ibid*, pp. 37-39.

[9]Levy, "Emerging North American Oil Balances," p. IV-22.

[10]*Ibid.*

[11]Cited in "Syncrude or Socialism? Developing Alberta's Oil Sands," by L. Pratt, revised version of a paper given to the Real Energy Conference, (Winnipeg, 8 March 1974).

[12]The government's policy statement is reprinted in Walwyn, Stodgill and Company, "A Look at World Energy: The Athabasca Tar Sands," (June 1973), pp. 39-45.

[13]*Ibid.*

[14]Levy, "Emerging North American Oil Balances," p. III-10.

[15]*Ibid.*

[16]The feelings on Canada's supply and demand outlooks would seem to have changed considerably. In its "Report to the Honourable Minister of Energy, Mines and Resources in the Matter of the Exportation of Oil," (October 1974), the National Energy Board stated that Canadian oil "producibility" would decline from 2.1 million barrels per day in 1975 to 1.51 million by 1982. Over the same time period, Canadian demand was to increase from 1.2 to 1.53 million barrels per day. Consequently, the NEB suggested that oil exports be phased out, and the federal government has adopted these policy measures. One might note that some authors question the realiability of the NEB projections given its previous "track record"; see Pratt, *The Tar Sands*, pp. 158-160, and "Syncrude or Socialism," p. 2.

[17]Levy, "Emerging North American Oil Balances," p. IV-17.

[18]Cited in *Oilweek* 25 (20 May 1974), p. 56.

[19]Walwyn and Stodgill, "World Energy," estimate that for an oil sands operation, the capital investment would be in the order of $6,000 to $7,000 per barrel per day (1973 current dollars), p. 28.

[20]Poyen, *Oilweek*.

[21]Levy, "Emerging North American Oil Balances", p. IV-17.

[22]See Levy, *ibid*, Appendix E.

[23]*Ibid*, p. III-21.

[24]The analysis presented here is based on the assumption that the price of oil will remain high. This may not be the case, and in fact, if the OPEC cartel should fail, prices would fall.

[25]This has actually been the case, but not due to enlightened American policies, but, rather, due to "enlightened" Canadian policies. See the National Energy Board, "Exportation of Oil".

[26]Levy, "Emerging North American Oil Balances", p. IV-19.

[27]Yurko, "Development of the Alberta Oil Sands".

[28]*Ibid*, p. 16.

[29]It would seem that "time" has passed by Yurko's "optimistic" projections. Shell and the other operators seem to want to wait on the "success" of Syncrude before they pursue their applications further.

[30]Anthony Scott, *Natural Resources: The Economics of Conservation* (Toronto: McClelland and Stewart Limited, 1973), p. 127.

[31]The Conservation and Utilization Committee, "Tar Sands Development Strategy", p. 1.

[32]*Ibid*, pp. 2-3.

[33]The Committee's report is criticized by Pratt, "Syncrude or Socialism", as being politically naive. "It completely . . . ignores the decisive fact that in Alberta political power is derivative, and that Lougheed and Co. hold power under rules of the game set by the oil cartel. It would be quite beyond Lougheed's capacity to put through any such policy, even if he wished to do so, precisely because the crucial decisions regarding the development of the oil sands are not being taken in Alberta, or even in Canada." pp. 5-6.

[34]The Conservation and Utilization Committee, "Tar Sands Development Strategy", pp. 46-47.

[35]"Oil sands development" is not to be thought of simply in terms of the extraction and partial refinement, but rather, in terms of the entire production cycle from development of inputs, through to, and including, the finished product. This cycle also includes all secondary industries whose operations stem from or are induced by the tar sands development.

[36]The Conservation and Utilization Committee, "Tar Sands Development Strategy", p. 48.

[37]*Ibid*, p. 53.

[38]*Ibid*, pp. 54-55.

[39]It would seem that the Committee is referring to the "fugitive" nature of the oil in the conventional pool. It is referred to as fugitive because of the indefiniteness of ownership or property rights. The resource must be "reduced to possession" or "captured through use" by the individual operators. Deferred use is subject to great uncertainty for others may "capture" the resource in the meantime. Hence, much of the information generated through exploration activities may be of a confidential nature. For example, the seismic operations by one operator on his lease may be extrapolated to adjacent areas by other operators. With the tar sands resource, on the other hand, the oil is quite viscous in nature and does not "flow" within the pool or deposit--thus, it is not of a fugitive nature. Furthermore, the ore deposits are quite different from lease to lease, calling for individual coring operations as distinct from the traditional seismic operations. The concept of a fugitive resource is developed in Ciriacy-Wantrup, *Resource Conservation*, pp. 141-145.

[40]The Conservation and Utilization Committee, "Tar Sands Development Strategy", p. 59. The Committee cites the Middle East experience as an example of the "leverage" that a government possesses.

[41]W. J. Yurko to J. Sauvé, 15 October 1974.

[42]Frank H. Knight, *Risk, Uncertainty and Profit* (Chicago: University of Chicago Press, 1971), pp. 347-348.

[43]*Ibid*, p. 349.

[44]*Ibid*, p. 350.

[45]In this context the safe minimum standard is to refer to development in general, as opposed to the more restrictive case employed by Ciriacy-Wantrup. The distinction between the two will be dealt with presently.

[46]Scott, *Natural Resources*, p. 128.

[47]Ciriacy-Wantrup, *Resource Conservation*, p. 251.

[48]*Ibid*, pp. 251-252.

[49]Environment Conservation Authority, "Review of Interaction Between Migratory Birds and Athabasca Oil Sands Tailings Ponds," (September 1975).

[50]J. V. Krutilla and A. C. Fisher, *The Economics of Natural Environments* (Baltimore: The Johns Hopkins Press, 1975), p. 45. One might note that the Krutilla/Fisher analysis refers to "unique scenic environments" with no close substitutes. Some might argue that the Alberta tar sands would not fall in this category.

[51]For example, the environmental impact assessment of the Syncrude project consists of three phases. The first phase was completed with the presentation of the first environmental impact statement in September of 1973. The second phase is to be completed just prior to commencement of production, and the third follows the second in ten years' time. Each of these can be considered as a "stage" of development. The new data presented must be carefully analysed, and the existing safe minimum standard subsequently modified appropriately--reflecting any advance in technology and economics.

[52]For example, consider the findings of the Regional DOE Syncrude Task Force, "Environment Canada Comments Relating to Documents Comprising the Syncrude Environmental Impact Assessment," (19 Auguest 1974), p. 4. They claim that, "Through the application of the best practicable technology, total SO_2 emissions can be reduced from 287 LT/SD to an estimated 40 LT/SD."

[53]Ciriacy-Wantrup, *Resource Conservation*, p. 253.

[54]The Conservation and Utilization Committee, "Tar Sands Development Strategy", p. 3.

[55]The optimum state of conservation can be defined as that time distribution of use rates that maximizes the present value of the flow of expected net social benefits. See Ciriacy-Wantrup, *Resource Conservation*, pp. 76-94, for a discussion of this concept.

[56]*Ibid*, p. 81.

[57]One must keep in mind that the estimated figures refer to the costs of reclamation in the case of coal strip-mining.

[58]For example, over the past few months there has been much debate as to the impact of sulphur dioxide emissions. With the installation of the "best practicable technology", the emissions can be reduced from 287 LT/SD to 40 LT/SD. Whether this will guarantee that the safe minimum standard is not encroached upon is difficult to ascertain without further research. It will, however, increase the costs of the firm.

[59]Rowland, *Fuelling Canada's Future*, p. 80.

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